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FISCAL YEAR 1992 AND 1993
NATIONAL SCIENCE FOUNDATION AUTHORIZATION

HEARINGS

BEFORE THE

SUBCOMMITTEE ON SCIENCE

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED SECOND CONGRESS

FIRST SESSION

FEBRUARY 20; MARCH 12, 13, 1991

[No. 22]

Printed for the use of the
Committee on Science, Space, and Technology

U.S. GOVERNMENT PRINTING OFFICE
42-730 ⇆ WASHINGTON : 1991

For sale by the Superintendent of Documents, Congressional Sales Office
U.S. Government Printing Office, Washington, DC 20402

H701-51

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FISCAL YEAR 1992 AND 1993 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

WEDNESDAY, FEBRUARY 20, 1991

U.S. House of Representatives,
Committee on Science, Space, and Technology,
Subcommittee on Science,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:30 a.m. in room 2318, Rayburn House Office Building, Hon. Rick Boucher [chairman of the subcommittee] presiding.

Mr. Boucher. The subcommittee will come to order.

This is the first day of authorization hearings for the National Science Foundation. We are pleased to have with us this morning Dr. Frederick Bernthal, the Acting Director of the Foundation, and Dr. Mary Good, who chairs the National Science Board.

Our witnesses this morning will be presenting plans and priorities in the proposed fiscal year 1992 budget, as well as discussing various aspects of the Foundation's current activities. Subsequent hearings of this subcommittee will be scheduled in March to provide an opportunity for non- Government witnesses to comment on the NSF's budget and priorities.

The fiscal year 1992 budget request for the NSF is 17.5 above the fiscal year 1991 appropriation level. This large increase, if approved, will keep the NSF on track, to double its budget relative to the fiscal year 1987 base year. This goal has consistently been endorsed by this subcommittee, and is reflected in the NSF's current five-year authorization.

It should also be noted that the NSF proposes new initiatives in the areas of advanced materials, high performance computing, and the establishment of a national research and education network. The budget also contemplates a new research instrumentation program. We will look forward to comments from our witnesses concerning the NSF's intention with respect to implementing these new programs.

NSF grants support the discovery of new knowledge, train new generations of scientists and engineers, and help improve science and math education in our Nation's primary and secondary schools. These programs are essential for sustaining the science base of the country, for raising the scientific literacy of our citizens, and for contributing to the storehouse of knowledge which powers our future economic growth. These are investments which will help secure our Nation's long-term prosperity and must be made even in a time of severe fiscal constraint.

We are pleased to have the opportunity this morning to hear how the NSF will allocate the resources in the budget request and in particular the rationale which led to the priorities that the NSF has identified. NSF faces a daunting array of competing demands. Great efforts are needed to upgrade science education in our schools. The costs of research are spiraling upward, along with the numbers of academic researchers who are seeking support.

There is a great need for resources to upgrade research laboratories, and new research opportunities proliferate in nearly every field of science and engineering. We hope from the discussions this morning to gain a better sense of the criteria the NSF uses to make choices among these competing needs.

Science and engineering education continues to be a focus of particular interest to this subcommittee. We are pleased to note a 21 percent increase in the fiscal year 1992 budget request for the NSF education directorate. We are interested in learning how the NSF plans to utilize these new monies, particularly as they relate to programs authorized in the Excellence in Mathematics, Science, Engineering and Education Act that was passed last year.

Dr. Bernthal and Dr. Good, we welcome you this morning. In a moment, we will be very pleased to hear your testimony.

First, I would like to call on the ranking minority member of this subcommittee, the gentleman from California, Mr. Packard, for his comments.

Mr. Packard. Thank you, Mr. Chairman. I look forward to working with you, and hope that we can establish the same kind of relationship that I enjoyed with my good friend, Ralph Hall, as I served as ranking member on the International Subcommittee previously.

The United States faces some very important and rather strenuous challenges to regain our global competitiveness, to address increasing environmental concerns and to tackle domestic social and economic problems. Research, together with educating the scientific talent of the future, is a vital and dynamic component in the drive to improve, over the long-term, the Nation's productivity and in the search to find answers to critical environmental questions.

NSF funded research and education activities provide new and important knowledge which often underlies advances in all areas that we have referred to, as well as National defense, health, energy and agriculture. The key role of basic science in this country's economic future is acknowledged by the President's fiscal budget of 1992, the Fiscal Year 1992 budget request, which is an increase of 17.5 percent for the National Science Foundation over the 1991 budget. This certainly does confirm the Administration's continued commitment to this program, and the desire to double the NSF funding over the next five-year period.

It also recognizes the overriding importance of education, the urgency of research on global change and the demand for greater computing resources.

I would like to welcome Dr. Fred Bernthal, the Acting Director, and Dr. Mary Good, Chairman of the National Science Board, to testify before us today. As a new member of this subcommittee, I look forward to continuing my education on these critical issues, and I certainly look forward to your testimony. Thank you for appearing.

Mr. **Boucher**. The Chair thanks the gentleman. Are there other members of the subcommittee who care to make opening statements this morning?

Yes, the gentleman from Maryland, Mr. Gilchrest.

Mr. **Gilchrest**. I would just like to make a comment. As a teacher up until November 6, I am excited to be here. To me science is another word for knowledge. If we are going to move into the next generation and be successful at being competitive, be successful at creating and enhancing the quality of life for inhabitants of this planet, be successful in the area of education, which needs an infusion of excitement, I think your organization can do that.

I think we need to come back to basic, fundamental facts. The decisions we face in the next generation and in the next century are going to be based on scientific facts, not necessarily political expediency, or anything other than what people like you can provide us. So with science being knowledge, and your research, I look forward to working with you, and I am excited to be here. I am looking forward to your presentation.

Mr. **Boucher**. The Chair thanks the gentleman.

Without objection, the—

Mr. **Roemer**. Mr. Chairman, if I might make one very quick comment.

Mr. **Boucher**. Yes, the gentleman is recognized.

Mr. **Roemer**. Thank you. I would like to make a comment, speaking as a former teacher as well, and also as somebody that is on the Education and Labor Committee. I am anxious to hear the testimony today, especially as it relates to improving science and math in our primary and secondary schools, how we encourage new technology in the schools. I think our children are very, very anxious to see and work with and are receptive toward this, and also I encourage you to be innovative today and propose any new ideas.

As my colleague from Maryland said, people are excited about it. After spending most of last week in schools in the Third District of Indiana, our kids, as well as our teachers and our business community, are very anxious to hear new ideas, hear about new ways to work with innovative technologies, as well. I am very curious and excited to hear what you will propose today.

Thank you, Mr. Chairman.

Mr. **Boucher**. The Chair thanks the gentleman.

Do any other members seek recognition?

If not, the prepared statements of the witnesses will be made a part of the record, and the subcommittee would be pleased to hear the comments of the witnesses in such order as they desire to proceed.

Dr. **Bernthal**. Mr. Chairman, I would just thank you for your comments, and I ask that the Chairman of the Board of the National Science Foundation lead off, Dr. Mary Good, who has a statement she would like to make.

STATEMENT OF DR. MARY GOOD, CHAIR, NATIONAL SCIENCE BOARD

Dr. Good. Thank you very much, Mr. Chairman and members of the subcommittee.

I am very pleased, number one, to see so many of you here this morning. We really do appreciate the interest and we are delighted to have the opportunity to talk to you about something we find very, very exciting and very important.

To place the 1992 budget request in perspective, I would like to reiterate a couple of things, which I know some of you already know, and some of you have already noted. But first, I think all of us understand that our Nation today is facing significant challenges across a wide range of fronts, perhaps more than we have ever seen, surely, in the last 100 years: the whole issue of competitiveness, the whole issue of the environment, the questions of health and the questions of education which some of you have already pointed out.

Now, in all of these areas, science, technology and human resources are going to be the important components of any of the solutions to those problems. So I think we need to consider the NSF's 1992 budget in the context of those challenges.

As part of last year's "Science and Engineering Indicators," the National Science Board provided a number of recommendations for strengthening American competitiveness in a section entitled "The State of U.S. Science." Although that statement was directed toward the Nation as a whole, the recommendations we provided are also integral to the mission of the National Science Foundation, and they really were the basis of our overall guidance of the budget preparation. Let me just share the bullets from those recommendations with you.

First, although the individual investigator—and I am going to go down through these, if you will bear with me, sort of from the top to the bottom, okay? We will get to the education ones, because they are so important. I want to spend a little bit more time on those, but let me also give you some of what we believe are extraordinarily important issues, at the top of these levels, as well. The individual investigator in the university remains the mainstay of scientific inquiry.

Also the mainstay of modern science and engineering research today is much more organized. It is much more capital intensive. It is much more multidisciplinary and cooperative than it has ever been in the past. Our universities need to adapt to that change, because it is a change from the way they have done business, perhaps, in the past. We particularly feel strongly that interdisciplinary research must be encouraged at all levels.

Now, in that recommendation, the NSF recognizes the dynamic character of research. Support for individual investigators is a very significant component of the budget you will hear about today. But other important needs, such as instrumentation and education, also receive special emphasis. The National Science Foundation must remain a leader in encouraging greater collaboration among disciplines, institutions and sectors of society, which in turn will improve our National competitiveness and provide a better way of life.

A second recommendation calls for dramatically improving precollege and undergraduate education. The whole issue of a well-educated work force I need not explain to this committee. All of you are already on track. But education and human resources continue to be high priorities at the National Science Foundation, and you will see that in the budget.

Precollege and undergraduate education will both experience double digit growth rates in 1992, if this budget is implemented. With these resources, the National Science Foundation could support approximately 7,000 precollege students, almost 20,000 precollege teachers, which is a very important issue, and you will hear more about it, and 12,000 undergraduate students.

Thirdly, we must encourage and persuade more of our best students to study science and engineering, at both the undergraduate and graduate levels. I reviewed the background of the members of this subcommittee, and I admit that the law is very important to do. But we do need some of our very best students today to go into science and engineering. This 1992 budget request has fellowships and research support to attract the brightest and the best.

But it also has programs to attract the underrepresented, which, as the demography of the country changes is as important, perhaps, as the programs we have done in the past. It calls for particularly expanded efforts in attracting women, minorities, and disabled students, who in many cases lack sufficient preparation or the guidance, if you will, to do science and mathematics.

The fourth recommendation that the Board made was more general, which really called for greatly strengthening the entire university basic research enterprise. We must remember that the universities are the source of many of the fundamental new ideas that drive innovation, and they provide all of the new research scientists and engineers for the country. So a major mission of the National Science Foundation is to strengthen the Nation's research base and the scientific infrastructure.

NSF's principal means of supporting research continues to be awards to individuals and small groups. But we also provide researchers with the vitally needed tools of the trade: scientific equipment and instrumentation. We will, in this budget, expand the support for both research and equipment with those resources. We should be able to support roughly 29,000 senior scientists and post-doctoral students, which is about a 12 percent increase over 1991, and provide them with the tools they need to conduct that research at the cutting edge.

University based research will also benefit directly from activities like the interagency High Performance Computing and Communications initiative, which you will hear more about. That will make supercomputing resources and data bases more accessible to researchers across the Nation.

The fifth recommendation is to develop better cooperation among industry, the universities, and the Government. Because this whole issue of science and science education is a national need, not just only the responsibility of the universities. Although the universities create the new ideas and educate the people, industry turns the ideas into products and drives economic growth. Research that is not rapidly incorporated into new products and processes fails to achieve the economic potential we will need.

The National Science Foundation centers programs are probably the best-known mechanisms for stimulating university-industry collaboration. In 1992, we will concentrate on broadening the capabilities of the existing centers, particularly with respect to education and human resources, rather than starting new centers. Because we have some that are somewhat anemic, and we need to bring those up to a reasonable level. We also launch a new State-Industry-University Cooperative Research Centers program, which will get state governments more actively involved in science and technology for local economic development.

Many other National Science Foundation programs require industrial collaboration. These include the High Performance Computing initiative. The new instrumentation initiative will also require collaborative support from industry, and certain of the education and human resources programs.

Last but not least, the last recommendation was that we must encourage greater international cooperation and sharing, particularly in basic research. This is fundamentally a function of the spread of science and engineering capability around the world. Whether we really like it or not, we can no longer just look internally. We must understand what is happening around the world, and we must understand where we are, competitively, if we are to stay ahead.

So this budget will expand opportunities for U.S. scientists and engineers to collaborate with their foreign counterparts and obtain international experience. Special attention will be placed on improving cooperation with Latin America, the Soviet Union and Eastern Europe. In addition, both of the major physical sciences projects which are here in the budget for construction, both LIGO and the 8-meter telescopes, will be coordinated with foreign partners who will provide significant funding for those activities.

In summary and in closing, the National Science Foundation recognizes it can help bolster competitiveness and maintain our strong science and education base through the activities outlined above. The budget you have may not solve all of our problems, but it will surely keep us on the path toward greater progress and accomplishment.

Thank you very much, Mr. Chairman, for the opportunity to make those comments, and I will be happy to answer any questions at the appropriate time.

[The prepared statement of Dr. Good follows:]

TESTIMONY OF DR. MARY GOOD,

CHAIR, NATIONAL SCIENCE BOARD

BEFORE THE SUBCOMMITTEE ON SCIENCE,

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

UNITED STATES HOUSE OF REPRESENTATIVES

FEBRUARY 20, 1991

Mr. Chairman, thank you for the opportunity to testify today on the budget request for the National Science Foundation.

Our Nation is facing significant challenges across a wide range of fronts -- competitiveness, the environment, health, education, and others. In all these areas, science, technology, and human resources will be important components of any solutions.

I believe that we must consider the NSF's 1992 budget request in the context of these challenges. As part of last year's "Science and Engineering Indicators," the National Science Board (NSB) provided a number of recommendations for strengthening American competitiveness. Although that statement was directed toward the Nation as a whole, the recommendations we provided are also integral to the mission of the National Science Foundation.

> "First, although the individual investigator remains the mainstay of scientific inquiry, modern science and engineering research is more organized, capital intensive, multidisciplinary and cooperative than in the past. Our universities must adapt to meet this need." ("The State of U.S. Science and Engineering: A View from the National Science Board," February 1990)

In every respect, NSF recognizes the dynamic character of research. Support for individual investigators is a significant component of the FY 1992 budget request, while other important needs, such as instrumentation and education, also receive special emphasis. NSF is also a leader in encouraging greater collaboration among disciplines, institutions, and sectors of society, which in turn will improve our national competitiveness.

> "Second, we must dramatically improve precollege and undergraduate education. Only a well-educated work force can exploit new knowledge effectively, and only a technically competent population can deal with the political issues that modern technology raises." (NSB, February 1990)

Education and human resources continue to be high priorities at NSF. Precollege and undergraduate education will both experience double-digit growth rates in 1992. With these resources, NSF could support approximately 7,000 precollege students, almost 20,000 precollege teachers, and 12,000 undergraduate students.

> "Third, we must persuade more of our best students to study science and engineering, at both undergraduate and graduate levels." (NSB, February 1990)

All our students should have the opportunity to pursue scientific and technical careers, if they so desire. However, many students, particularly women, minorities, and disabled students, often lack sufficient preparation or guidance for such study.

Consequently, the National Science Foundation will greatly expand its efforts to encourage more women, minorities, and other underrepresented groups to study science, engineering and mathematics. NSF will also expand its programs to encourage more students to undertake the rigors of graduate study. These programs include components aimed at women and minorities.

> "Fourth, we must greatly strengthen university basic research. Universities are the source of most of the fundamental new ideas that drive innovation, and of all new research scientists and engineers." (NSB, February 1990)

A major mission of the National Science Foundation is to strengthen the Nation's academic research base and scientific infrastructure. NSF's principal means of supporting research continues to be awards to individuals and small groups. NSF also provides researchers with vitally needed "tools of the trade" -- scientific equipment and instrumentation.

NSF will expand its support for both research and equipment in 1992. With these resources, NSF would be able to support roughly 29,000 senior scientists and postdoctoral students -- a 12% increase over 1991 -- and provide them with the tools they need to conduct cutting-edge, competitive research. University basic research will also benefit directly from activities like the interagency High-Performance Computing and Communications (HPCC) initiative, which will make supercomputing resources and databases more accessible to researchers across the Nation.

> "Fifth, we must develop better cooperation among industry, universities, and governments. Although universities create the new ideas and educate the people, industry turns ideas into products and thus drives economic growth. Research that is not rapidly incorporated into new products and processes fails to achieve its economic potential." (NSB, February 1990).

NSF's centers programs are probably the best-known mechanisms for stimulating university-industry collaboration. In 1992, NSF will concentrate on broadening the capabilities of existing centers, particularly with respect to education and human resources, rather than starting new centers. NSF will also launch a new

State/Industry/University Cooperative Research Centers (S/IUCRC) program, which will get state governments more actively involved in science and technology for local economic development.

Many other NSF programs require industrial collaboration. These include the HPCC initiative, the new instrumentation initiative, and certain education and human resource programs.

> "Six, we must encourage greater international cooperation and sharing in basic research. This is fundamentally a function of the spread of science and engineering capabilities around the world. We can no longer depend entirely on our own resources to stay ahead." (NSB, February 1990)

NSF will expand opportunities for U.S. scientists and engineers to collaborate with their foreign counterparts and obtain international experience. Special attention will placed on improving cooperation with Latin America, the Soviet Union, and Eastern Europe. In addition, both of the major physical sciences projects under construction -- LIGO and the 8-meter telescopes -- will be coordinated with foreign partners.

In summary, the National Science Foundation recognizes it can help bolster competitiveness through the activities outlined above. This budget may not solve all our problems, but it will keep us on the path toward greater progress and accomplishment.

Thank you, Mr. Chairman. I would be happy to answer any questions you may have.

Mr. BOUCHER. Thank you, Dr. Good. We will withhold questions until after both witnesses have made their comments.

Dr. Bernthal, we will be happy to hear from you.

STATEMENT OF DR. FREDERICK M. BERNTHAL, ACTING DIRECTOR, NATIONAL SCIENCE FOUNDATION; ACCOMPANIED BY: JOHN WHITE, ASSISTANT DIRECTOR OF ENGINEERING

Dr. BERNTHAL. Thank you, Mr. Chairman. Before I proceed, Mr. Chairman, I would like to introduce one of the other actors here today, other than myself, that is, and that is the gentleman to my left, Dr. John White, who has the normal task within the Foundation of being the Assistant Director of Engineering for that directorate. He is on leave from Georgia Tech University and has been of great assistance to me in the Foundation in this interim period, while we are awaiting the arrival and confirmation of our permanent director, Dr. Walter Massey.

It is a pleasure especially to appear before you today, Mr. Chairman, to present the National Science Foundation's budget request for fiscal year 1992. In fact, I think I can probably derive more pleasure from that task today than many others may in these difficult budget times.

Earlier this month, Mr. Chairman, you became the new chairman of this particular new subcommittee, and I want to congratulate you on assuming what I am sure you will agree is a very important new post, and offer my personal pledge to assist you in any way I can. The NSF has benefitted greatly from the support of this subcommittee in the past, and we all look forward to working as closely as possible with you, and a number of your colleagues, including many of your new colleagues here, to maintain this committee's long-standing record of support for the Foundation.

The recent reorganization of the Committee on Science, Space, and Technology, Mr. Chairman, helps to highlight the importance of science and technology. Science and technology have never offered more new ideas and opportunities than they do today. New knowledge, created and applied through science and technology, has become a critical resource, a resource we are going to need to address the problems of a changing world.

But unlike natural resources, the resource of knowledge has to be replenished through a continuing investment in science and technology research, and of course, education.

Mr. Chairman, the President's budget request for the National Science Foundation reflects this new reality. The NSF proposes to invest in fiscal year 1992 a total of $2.72 billion in education and research. As you pointed out, this is a 17.5 percent increase over last year's level. This increase reaffirms the President's commitment to double the Foundation's budget by 1994, a target that over the last several years has been strongly supported by the Congress.

The Foundation's human resource development mission represents the fastest growing portion of this budget. The President has proposed to increase further the NSF's commitment to education and human resources development by 23 percent in fiscal year 1992, bringing the total level of effort to $456 million. Significant double digit increases are proposed for activities at every educational level, pre-school, undergraduate, and graduate, and beyond, as well.

As part of this mission, the President has asked the NSF to expand its efforts to encourage more representatives of underrepresented groups—women, minorities, disabled—to enter scientific and technical fields. The National Science Foundation budget includes almost $100 million for these efforts in fiscal year 1992, approximately a 25 percent increase above the 1991 level.

Included among these outreach efforts is a new program, the Alliances for Minority Participation, to be funded at $10 million in fiscal year 1992, and plan to generate comprehensive, coordinated approaches to increase the numbers and strengthen the skills of minority students receiving baccalaureate degrees. NSF is also working more closely with state governments and educational agencies throughout the NSF's new State-Wide Systemic Initiative program, which we hope will help states develop comprehensive, coordinated reforms to improve precollege science education. NSF proposes to increase this effort by nearly 50 percent, to $31 million in fiscal year 1992.

Our Experimental Program to Stimulate Competitive Research, the so-called EPSCoR program, is designed to assist those states that have been less competitive in obtaining Federal R&D support. The Foundation proposes to increase that funding effort by more than one-third, to $15 million in fiscal year 1992. NSF's vital mission to strengthen the Nation's research base and infrastructure is reflected in the President's requested increase of 17 percent for NSF research and equipment, bringing this total to nearly $2 billion in fiscal year 1992.

Again, double digit increases are being requested for every research activity of the Foundation. These proposed increases are aimed this year primarily at the individual investigator and small research groups that traditionally, for so many years, have formed the foundation of our research leadership.

Next year will mark the beginning of several new research initiatives as well, working with other Federal agencies through the FCCSET process. NSF will begin a new emphasis on High Performance Computing and Communications, as Dr. Good has pointed out. Our portion of this interagency initiative will be $213 million in fiscal year 1992, and I would point out that that forms roughly one-third of the entire Federal Government effort in this arena, even though we have about three percent of the total Federal budget for research and development.

The President has also directed NSF to expand its support for the U.S. Global Change Research Program, another interagency initiative coordinated through the FCCSET process. Our support for global change research will increase by more than one-third to $119 million in fiscal year 1992. Overall, the President has proposed increasing Federal support for global change research by nearly one-quarter in fiscal year 1992, in addition—on top of, I should say—to the 57 percent increase which was carried through last year.

The National Science Foundation will also begin a new initiative that is really a Foundation initiative, in Materials Synthesis and Processing. Materials undergird the critical technologies of the future, including semiconductors, superconductors, photonics, advanced ceramics, and biomolecular materials. Building on an existing research base within the Foundation, this initiative will total $84 million in fiscal year 1992, and that represents, Mr. Chairman, a 42 percent increase over fiscal year 1991.

Finally, Mr. Chairman, NSF identifies scientific equipment and instrumentation as a very high priority in this research budget. The President has proposed to increase our support for scientific equipment by 35 percent to $392 million in the next fiscal year. This includes a special $50 million Presidential initiative for state-of-the-art academic research instrumentation.

The instrumentation budget also includes two very important major projects that Dr. Good has already mentioned. We request a total of $40 million for these two activities: to begin construction of the first of two 8-meter optical telescopes as well as the Laser Interferometer Gravitational-Wave Observatory. I got through that whole name. We call it LIGO, normally. I will be happy to try and explain it a little further. Both of these projects, Mr. Chairman, will substantially advance our understanding of the universe and its basic physical principles.

Mr. Chairman, over the last half century, this country has built an extraordinary base in research and education and especially an extraordinary base in the academic research university community. The challenges of the next century will require a vigorous commitment to research and human resources and science and engineering.

The National Science Foundation's fiscal year 1992 budget request represents a sound investment in that future, and the people and the knowledge base that will enable this country to respond to the many competitive, environmental and social challenges that face our country today. With your support and the support of the entire subcommittee, that request and the benefits it can bring to our country can become a reality.

Thank you very much, Mr. Chairman.

[The prepared statement of Dr. Bernthal follows:]

TESTIMONY OF
DR. FREDERICK M. BERNTHAL
ACTING DIRECTOR, NATIONAL SCIENCE FOUNDATION
BEFORE THE
SUBCOMMITTEE ON SCIENCE
OF THE
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES
FEBRUARY 20, 1991

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE:

It is my pleasure to appear before you today to present the National Science Foundation's budget request for Fiscal Year 1992. Mr. Chairman, earlier this month you became the new chairman of this particular subcommittee. I want to congratulate you on assuming this key post and offer my own personal pledge to assist you in any way possible. NSF has benefitted greatly from this subcommittee's support in the past. I look forward to working as closely as possible with you and your colleagues to maintain this subcommittee's long-standing record of support for the Foundation.

The recent reorganization of the Committee on Science, Space, and Technology helps to highlight the importance of science and technology. Science and technology have never offered more new ideas and opportunities continue than they do today.

New knowledge, created and applied through science and technology, is the critical resource we need to address the problems and promises of a changing world. Yet unlike natural resources, the resource of knowledge can be -- and must be -- replenished through continuing investments in science, technology, and education. Yesterday's knowledge and abilities will not be sufficient for tomorrow. To succeed as a nation requires a large and continuing investment in the future to educate our citizens and to create new ideas. Highly educated scientists and engineers and a technically competent workforce are essential for the nation's future.

Our Nation's competitive posture, our ability to grapple with environmental problems, and our continued progress toward solving other complex economic and social challenges will depend to a very large extent on the vitality of our scientific, technological, and educational enterprises. Through his FY 1992 Budget Request, the President has asked the National Science Foundation to play a vital role in preparing this Nation to meet the challenges of the 21st century.

OVERVIEW OF FY 1992 BUDGET REQUEST

The President's budget request for the National Science Foundation reflects this new reality. NSF proposes to invest in Fiscal Year 1992 a total of $2.72 billion in education and research, a 17.5% increase over the 1991 level. This increase reaffirms the President's commitment to double the Foundation's budget by 1994, a target that has been strongly supported by Congress.

This commitment was made in recognition of the importance of NSF's twofold mission. First, NSF stimulates the development of human resources, encourages broader participation in the sciences by groups and regions that have not fully enjoyed their benefits, and helps to improve science, mathematics, and engineering education and training at all education levels. Second, NSF supports and strengthens the nation's research base and scientific and technical infrastructure. These missions are pursued through a competitive, merit-review process that identifies and rewards excellence and innovation in the research and educational communities.

The Foundation's human resource development mission represents the fastest growing portion of NSF's budget. As part of an interagency mathematics and science education initiative coordinated through the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), the President has proposed to increase further NSF's commitment to education and human resource development by 23% in FY 1992, bringing its total effort to $456 million. Significant, double-digit increases are proposed for activities at every educational level, from pre-school and elementary school through graduate school and beyond. With these resources, NSF will be able to support nearly 60,000 graduate students, undergraduates, and precollege teachers and students, over 7,000 more people than in 1991.

As part of this mission, the President has asked NSF to expand its efforts to encourage more representatives of underrepresented groups (i.e. women, minorities, and disabled students) to enter scientific and technical fields. These groups represent increasingly significant portions of the Nation's workforce, yet historically they have had very low participation rates in the sciences. NSF's budget includes almost $100 million for these efforts in FY 1992, roughly a 25% increase above the 1991 level.

Included among these outreach efforts is a proposal to continue a new program -- Alliances for Minority Participation (AMP). The Alliances program, to be funded at $10 million in FY 1992, will generate comprehensive, coordinated approaches to increase the numbers and strengthen the skills of minority students receiving baccalaureate degrees.

NSF recognizes that it is not alone in its efforts to improve educational quality and achievement. In addition to its traditional support for individual institutions and academic consortia, NSF is working more closely with state governments and educational agencies. NSF's Statewide Systemic Initiative (SSI) program, which will make its first awards in 1991, will help states develop comprehensive, coordinated reforms to improve precollege science education. NSF proposes to increase SSI by nearly 50% to $31.0 million in FY 1992.

NSF is also working with certain states to improve their participation in the science and technology enterprise. NSF's Experimental Program to Stimulate Competitive Research (EPSCoR) is designed to assist those states that have been less competitive in obtaining federal R&D support. NSF proposes to increase EPSCoR funding by 36% to $15 million in FY 1992 in order to stimulate state efforts to improve science and engineering education as well as academic research.

NSF's vital mission to strengthen the Nation's research base and infrastructure is reflected in the President's requested increase of 17% for NSF research and equipment, bringing this total to nearly $2 billion in FY 1992. Double-digit increases are requested for every research activity.

These proposed increases are aimed primarily at individual investigators and small research groups. With these resources, NSF would be able to support roughly 29,000 scientists and postdoctoral students, a 12% increase from the preceding year.

Next year will mark the beginning of several new research initiatives. Working with other federal agencies through the FCCSET process, NSF will begin a new emphasis on High Performance Computing and Communications. This initiative will greatly improve supercomputing and communications technology, while making computing resources more accessible to researchers and educators across the nation via a high-speed, high-volume computer network. This initiative has tremendous and direct implications for improving not only America's education and research capabilities but also industrial competitiveness across a wide range of fields. NSF's portion of this interagency computing initiative will be $213 million in FY 1992, one-third of the total federal effort.

The President has also directed NSF to expand its support for the U.S. Global Change Research Program, another interagency initiative coordinated through FCCSET. This research will enable scientists to better understand and predict global warming, including its economic and human impacts. NSF's support for global change research will increase by 36% to $119 million in FY 1992. Overall, the President has proposed increasing federal support for global change research by 24% in FY 1992, in addition to the 57% increase provided last year.

NSF will also begin a new initiative in Materials Synthesis and Processing. Materials undergird the critical technologies of the future, including semiconductors, superconductors, photonics, advanced ceramics, and biomolecular materials. Building on an existing research base, this initiative will total $84 million in FY 1992, a 42% increase over 1991.

These and other important activities require not only the talents and skills of scientists and engineers, but also the tools to enable them to conduct cutting-edge research. As mentioned earlier, NSF identifies scientific equipment and instrumentation as very high priorities in its research budget. The President has proposed to increase NSF's support for scientific equipment by 35% to $392 million in FY 1992.

This increase includes a special $50-million Presidential initiative for state-of-the-art academic research instrumentation. NSF's current funding mechanisms are insufficient to support the acquisition of the very large and expensive research equipment that is needed to retool America's academic laboratories and to advance its education and research efforts. This program will make awards in the range of $100,000 to $2 million and will require at least a dollar-for-dollar match from non-federal sources.

The instrumentation budget also includes two very important major projects. NSF requests a total of $40 million to begin construction of the first of two 8-meter optical telescopes as well as the Laser Interferometer Gravitational Wave Observatory (LIGO). Both projects will substantially advance our understanding of the universe and its basic physical principles.

While the budgetary gains I have described are impressive, the hard fact is that demands from universities, schools, and industries are outstripping the Foundation's ability to support them. Scarce resources must be directed toward those activities that will be most fruitful and are likely to offer the most immediate return for the investment. The Foundation believes that this situation requires that we concentrate on the particular needs for investigator support, instrumentation, and specialized major equipment at this time. Thus, the Foundation is not requesting any funds to continue the academic research facilities modernization program in FY 1992.

DETAILED DISCUSSION OF FY 1992 BUDGET

The FY 1992 Budget Request reflects the Foundation's top programmatic priorities: education and human resources; the research base and instrumentation; and competitiveness. It responds to today's many new opportunities as well as to new challenges.

EDUCATION AND DEVELOPMENT OF HUMAN RESOURCES

The education of future scientists and engineers and of a technically competent workforce is critical for the development of new technologies, products, and an improved competitive posture. The FY 1992 Request responds to national concerns in this area with an increase of 19 percent for programs across the Foundation, and reflects a strategic framework for a significant and balanced investment in education.

Mr. Chairman, the Congress has consistently shown strong support for science and engineering education, most recently demonstrated by the passage last year of the "Excellence in Science, Mathematics, and Engineering Education Act." This legislation provides an important framework for addressing the problems we face at all levels of education, and in both formal and informal settings.

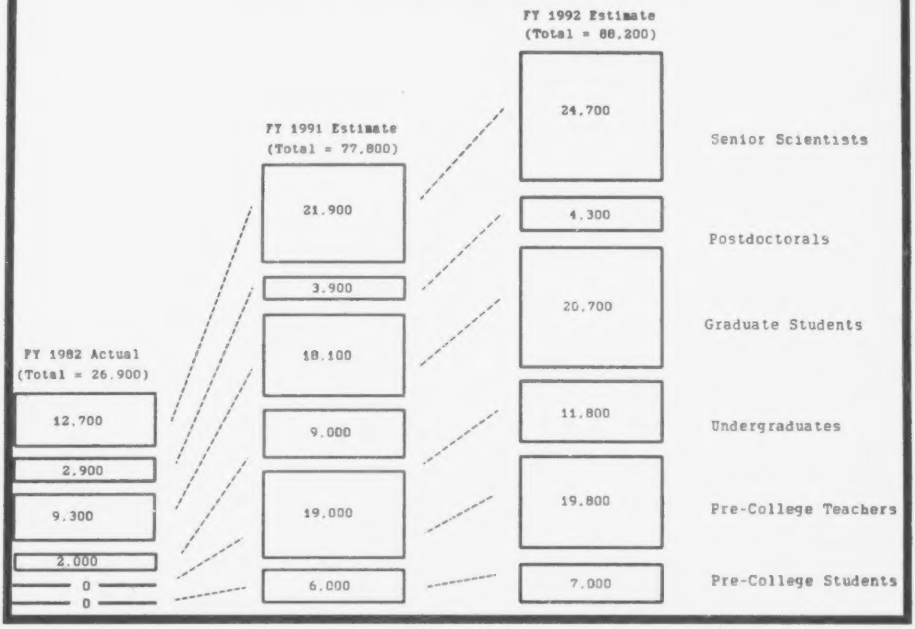
NSF serves as a catalyst in the area of science and engineering education -- fostering connections among institutions, disseminating knowledge, and bringing together talented people. Foundation programs are designed to address both the qualitative and quantitative deficiencies manifest at all critical points in the educational process. While these efforts occur in programs funded throughout the Foundation, the Education and Human Resources Activity serves as a focal point for these efforts.

The Foundation is active at all levels of education: precollege, undergraduate, graduate, and postgraduate (Figure 1). The Foundation's programs in these areas are coordinated through the FCCSET Committee on Education and Human Resources. Such coordination is intended to optimize the use of limited federal resources, while drawing on the specialized expertise within agencies. The Foundation activities support the plan presented in the FCCSET report "By the Year 2000: First in the World".

Foundation programs also directly contribute to the National Education Goals for mathematics and science education developed which resulted from the President's Education Summit in 1989:

Figure 1.

National Science Foundation
Support for Science & Engineering Personnel



- By the year 2000...every school in America will ensure that all students learn to use their minds well, so they may be prepared for responsible citizenship, further learning, and productive employment in our modern economy.
- By the year 2000, U.S. students will be first in the world in science and mathematics achievement.
- By the year 2000, every adult American will...possess the knowledge and skills necessary to compete in a global economy.

Highlights of the Foundation's FY 1992 Request for education and the development of human resources include:

Pre-College Programs

Pre-college science and mathematics courses must meet the future needs of all students: those who will perform technical jobs crucial to the Nation's economy as well as those who will become professional scientists and engineers; and all of us who as citizens must make decisions on the science- and technology-based issues facing society. This commitment is built into all the Foundation's pre-college programs.

Precollege programs are the largest component of NSF's efforts in education, training, and human resources development, totalling over $250 million in FY 1992 and exceeding the levels of the 1960's. Programs focus on improving the effectiveness of elementary and secondary school science and mathematics instruction. NSF provides leadership and expertise in this area, and serves as a catalyst in our national effort to introduce change and improvements in our educational institutions.

Our success in improving the performance of our students depends on contributions from all institutions, state and Federal, public and private. It also depends on a commitment to excellence on the part of every parent, student, and teacher. The Foundation believes that cooperation among major institutions in these efforts will play a critical role in meeting future challenges. As part of these efforts, the **Statewide Systemic Initiatives** program, an effort to develop federal-state cooperation in restructuring precollege education, will double its funding.

Programs in **Teacher Enhancement** and **Teacher Preparation** will develop innovative and exemplary programs for science and mathematics teachers. Efforts to develop resource and curriculum materials for pre-service and in-service use to promote more effective teaching practices will be expanded.

The Foundation will support approximately 7,000 pre-college students and almost 20,000 pre-college teachers in FY 1992.

Undergraduate Programs

Undergraduate programs will total $132 million in FY 1992. In particular, **Course and Curriculum Development** programs will be expanded in an effort to revitalize introductory-level courses in all fields of science, engineering and mathematics. NSF will stress the importance of introductory, undergraduate courses to the preparation of future elementary and secondary school science and mathematics teachers. A separate, targeted calculus efforts will continue through FY 1992, emphasizing dissemination of promising approaches which have been developed.

The **Research Experiences for Undergraduates** program, which provides support for undergraduates to actively participate in research projects, will receive additional emphasis in FY 1992. The Foundation is particularly interested in increasing the participation in research of underrepresented groups (i.e. women, minorities and persons with disabilities).

The Foundation will provide support to almost 12,000 undergraduate students in FY 1992.

Graduate Programs

The **Graduate Fellowships, Minority Graduate Fellowships, and Graduate Fellowships for Women in Engineering** programs will continue at the combined level of 1100 new fellowship offers in FY 1992. The selection of outstanding students in all fields of science and engineering to be Fellows helps prepare the Nation to face the research challenges of the future. Funding for graduate research assistants within the disciplinary awards will increase, as will support for post-doctoral researchers.

The Foundation will support about 25,000 graduate students and post-doctorates in FY 1992.

Broadening the Participation of Underrepresented Groups

Over the next decade, underrepresented groups in the science and engineering fields (i.e. women, minorities and persons with disabilities) will represent an increasing proportion of the nation's potential workforce. At all levels of education and research, NSF has special programs for minority institutions and for women, minority and disabled students and investigators to increase the participation and performance of these groups in future scientific and engineering efforts. The FY 1992 Request includes approximately $100 million for these efforts, roughly 25 percent above the FY 1991 level. In addition to existing programs to assist underrepresented groups such as Facilitation Awards for the Handicapped, Research Improvement in Minority Institutions, and Graduate Engineering Education for Women, Minorities, and Persons with Disabilities, the FY 1992 Request includes:

- The **Alliances for Minority Participation (AMP)** program will generate a comprehensive, coordinated approach to increase the number and to strengthen the skills of minority students receiving baccalaureate degrees and subsequently beginning graduate study in science, engineering and mathematics. AMP aims to stimulate the establishment of broad-based regional and national alliances of academic institutions, school districts, state and local governments, and the private sector that are dedicated to improvement of undergraduate education.

- **Faculty Awards for Women** permit recognition of women scientists, strengthen their capabilities for research and teaching, increase their visibility as effective role models, and accelerate their movement to senior-level ranks in science and engineering.

- The **Experimental Program to Stimulate Competitive Research (EPSCoR)** responds to NSF's mandate to insure the health of science and engineering nationwide by assisting states that have been relatively less competitive in obtaining Federal R&D support. EPSCoR will receive a 36 percent increase in FY 1992 to initiate an Advanced Development Program to institute comprehensive development efforts in up to ten states.

RESEARCH AND INSTRUMENTATION

Support for research and infrastructure accounts for approximately 75 percent of the FY 1992 Budget Request. These research and instrumentation programs will make significant contributions to improving the Nation's scientific and technical capabilities. The FY 1992 Budget Request is an increase of almost 17 percent over FY 1991.

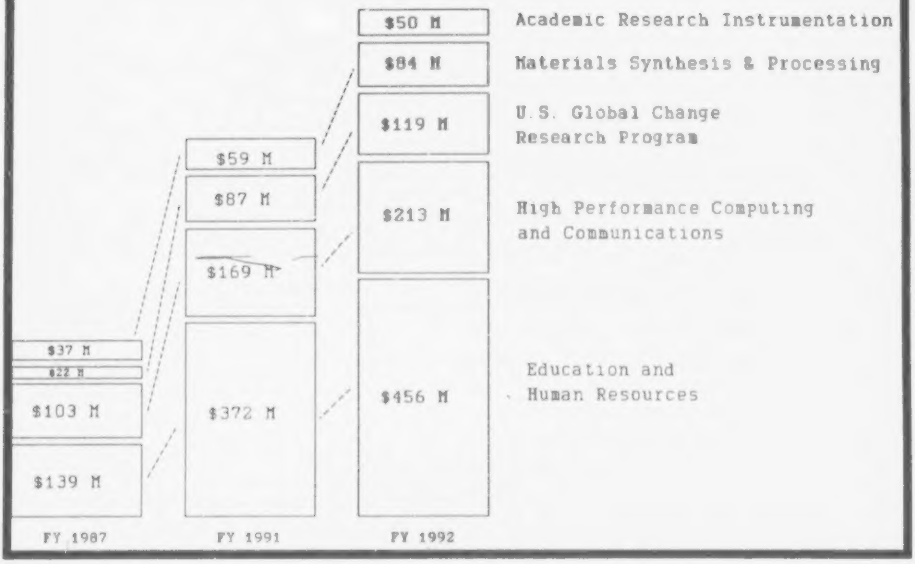
The Request emphasizes support for **Individual Investigators**, primarily at the Nation's colleges and universities, and the research infrastructure required to meet their needs. Individual investigators continue to serve as the indispensable backbone of the nation's research system. The Request includes continued growth for forefront, high-priority areas such as materials research, biodiversity, plant sciences, global change research, computational sciences and high performance computing, as well as support for basic disciplinary research. Support for investigator-initiated disciplinary research and for infrastructure increases to $1.28 billion in FY 1992, an 18 percent increase over the FY 1991 level.

The FY 1992 Budget Request for NSF includes programs to develop further the nation's opportunities. Initiatives in High Performance Computing and Communications, Materials Synthesis and Processing, and the U.S. Global Change Research Program exemplify NSF's role in the national research enterprise. A major initiative in Academic Research Instrumentation will ensure the vital infrastructure needed for the nation's exciting future. Increases for these initiatives and the FCCSET initiative for Education and Human Resources discussed previously are shown below (Figure 2).

Although NSF provides only 3% of Federal funds for research and development, it plays a substantial role in several critical high-priority areas (Figure 3). Many of these areas reflect the growing complexity and multi-disciplinary nature of today's research problems, evidenced by increasingly coordinated research, shared data, and common instrumentation and equipment. Highlights include:

Figure 2.

National Science Foundation
FY 1992 Major Initiatives



- **High Performance Computing and Communications:** Progress and productivity in modern research increasingly depends on the management of large, complex databases, the exercise of massive computer models, access to costly or distant computing resources, and communication among scientists and engineers. The Foundation's Request supports this interagency initiative, coordinated through the Federal Coordinating Council on Science, Engineering and Technology (FCCSET), to provide the computing and networking infrastructure for research in all science and engineering disciplines.

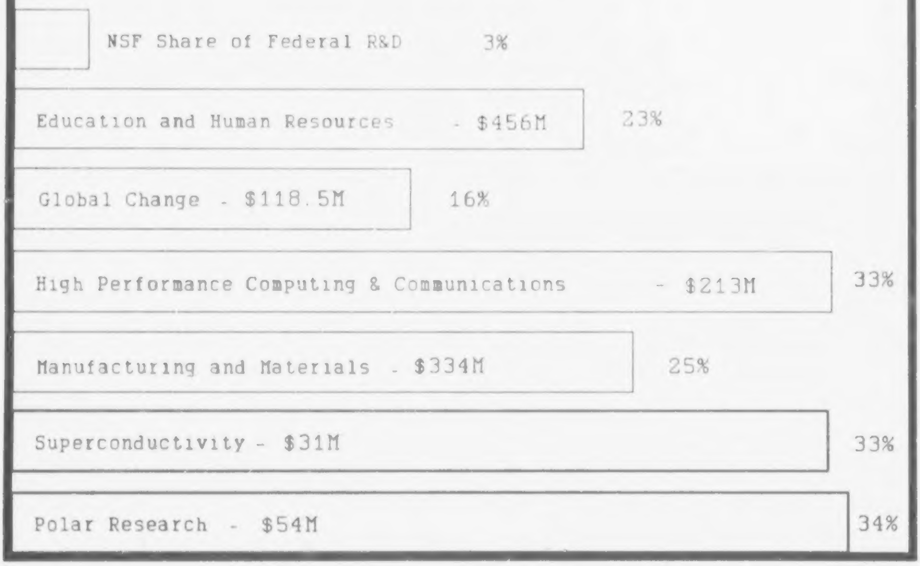
  The HPCC initiative will sustain U.S. competitiveness by developing the enabling technologies necessary for computing and communications systems and by accelerating technology transfer. It provides for the use of improved computing and communications technologies to contribute to more effective solutions to the major challenges facing the nation.

This initiative will also improve the educational process at all levels by enabling educators to integrate new knowledge and new methods into courses. Students at all levels will be drawn into a wide variety of research and learning experiences as part of the initiative. NSF funding for the HPCC initiative will total $213 million in FY 1992.

- **U.S. Global Change Research Program:** The Foundation's Request supports the FCCSET Committee on Earth and Environmental Sciences FY 1992 plan to expand the scope and interagency responsibility for this important program. As one of nine federal agencies engaged in this initiative, NSF focuses its support on the basic research necessary to understand, and ultimately predict, future changes in the earth's environment, and the human dimensions associated with these changes. The Foundation's support for this program will total $118.5 million in FY 1992.

Figure 3.

NSF Share of Federal Support
FY 1992 Request



- **Materials Synthesis and Processing:** A new NSF initiative, totalling $84 million, will strengthen the fundamental sciences and engineering capabilities undergirding the critical technologies of the future, and enhance the abilities of U.S. industry in developing and using next-generation materials and novel processing methods. Potential fields of research include semiconductors, advanced ceramics, photonics, and biomolecular materials. Special attention will be given to individual investigators and small, multidisciplinary research groups.

- **Academic Research Instrumentation:** A new $50 million program is designed to improve the research infrastructure by funding the development and acquisition of state-of-the-art instrumentation. This program will support the acquisition of the major modern scientific instruments needed to retool the nation's academic laboratories and advance the nation's research and research training efforts. It will encourage greater accessibility and utilization of instruments, and provide for maintenance and technical support for research instrumentation. Cost sharing of at least 50 percent from non-Federal sources will be required.

Major Research Equipment

The Foundation has long been a source of support for unique, major national facilities such as telescopes, research ships, and supercomputers, as well as for instrumentation integral to research capabilities. The Request continues its commitment to provide individual investigators with access to world-class instrumentation and facilities. Among the highlights are:

- Verification of the existence of gravitational waves and black holes and the measurement of their properties offer the opportunity to open a new window onto the universe. These are the objectives of U.S. scientists designing the **Laser Interferometer Gravitational Wave Observatory** (LIGO). NSF will begin construction of two identical, but widely separated, detectors in FY 1992 with a request of $23.5 million, for a total estimated cost of $211 million over five years. Two European groups are planning to build complementary detectors of compatible design and costs similar to the LIGO facility. These detectors, working in concert with LIGO, will permit systematic astrophysical observations in the new field of gravitational wave astronomy. Such international cooperation provides a major opportunity to lower national cost by sharing development, construction and operational expenses necessary to begin research in an entirely new field.

- Technological advances in key areas of telescope construction present an opportunity to push telescope performance to new standards of excellence. Construction of two **8-meter optical/infrared telescopes**, one each in the northern and southern hemisphere, will be jointly funded by the U.S. and the United Kingdom, with Canada as a third prospective partner. Construction of the first telescope will begin in FY 1992 at a level of $16 million. The project is estimated to take 8 years to complete at a total cost of $176 million, of which the U.S. will provide half.

U.S. Antarctic Program

The **U.S. Antarctic Program**, which is managed by the Foundation, supports national goals in the Antarctic: to maintain the Antarctic Treaty; to ensure that the continent continues to be used only for peaceful purposes; to maintain an active and influential presence; to foster cooperative research contributing to the solution of regional and world-wide problems; and to protect the environment.

A major, multi-year **Safety, Environment, and Health Initiative (SEH)**, which began in FY 1990, continues to expand in FY 1992 to remedy concerns in these areas. A comprehensive approach to improvements in these areas is necessary to deal with problems that have accumulated and to meet higher standards. The FY 1992 Budget Request includes $31.0 million for the SEH initiative, or an increase of $6.0 million over FY 1991, to fund upgrades of medical facilities, the provision of field safety experts as members of science field parties, and McMurdo Station waste disposal and hazardous waste handling facilities.

COMPETITIVENESS

The ability of this National to compete effectively increasingly depends on a large and continuing investment in the future to educate our citizens and to create new ideas. Highly educated scientists and engineers and a technically competent workforce are essential for the nation's future. Yesterday's knowledge will not be competitive tomorrow, and individuals must continue to learn new skills and new ideas.

Our Nation's competitive posture, our ability to grapple with environmental problems, and our continued progress toward solving other complex economic and social challenges will depend to a very large extent on the vitality of our scientific, technological, and educational enterprises. Through initiatives such as High Performance Computing and Communications and Materials Synthesis and Processing and through ongoing programs including the Industry/University Cooperative Research Centers and Small Business Innovation Research (SBIR), the Foundation continues to stimulate technological development and to support U.S. competitiveness.

Research Centers

NSF maintains its commitment to support research centers, including Engineering Research Centers (ERC's) and Science and Technology Centers (STC's). These centers encourage partnerships between universities, government, and the private sector, promote research on complex, large-scale research problems, and provide students with experience in interactive, multidisciplinary research settings.

In FY 1991 the Foundation plans to fund up to 14 new Science and Technology Centers in fields of science across the Foundation. The 14 proposed centers include participation from 54 universities and colleges in 20 states, four national laboratories and four nonprofit centers.

While the Foundation will not initiate any new STC's or ERC's in FY 1992, NSF will augment funding for its existing centers, particularly for activities for undergraduate students. These efforts will allow the existing centers to mature and develop.

CONCLUSION

In conclusion, Mr. Chairman, over the last half century the Nation has built an extraordinary base in research and education. The challenges of the next century will require a vigorous commitment to research and human resources in science and engineering. The decade of the 1990's will be critical for investing in the nation's future, positioning the U.S. to be not only first in mathematics and science education, but also first with the knowledge and capability to move forward in competitive areas.

The National Science Foundation's FY 1992 Request is one step to provide the critical resources necessary to strengthen this research base, to develop new and exciting opportunities, and to create and employ new knowledge. The FY 1992 Budget Request represents a sound investment in the future -- in the people and the knowledge base that will enable our Nation to respond to the many competitive, environmental, economic, and social challenges that it faces today. With your support, that request -- and the benefits it will bring to our country -- can become a reality.

Mr. **Boucher**. Thank you, Dr. Bernthal and Dr. Good, for your informative statements this morning, and your attendance at this hearing.

I notice that in your budget request for fiscal year 1992, you have a new initiative for new instrumentation at research institutions. That is funded to the extent of $50 million. What is absent, however, from the budget request, is any amount of funding for that initiative that this subcommittee has long endorsed, and for which there is a current authorization of $250 million, and that is funding for research facilities. During the past two years, that program has been funded at $19 million and at $20.6 million, respectively.

I would welcome any comments you have about the success of the program to date, in terms of the expenditures that have been made, your anticipation or estimate of current and future needs that institutions have for the modernization of research facilities and the addition of research facilities, and any rationale that you care to offer for why there is no funding requested for that program for fiscal year 1992.

Dr. **Bernthal**. Well, Mr. Chairman, it is a question of priorities, ultimately. I would say also, reflective of the magnitude of one problem and the priority that we attach to the instrumentation area. The academic facilities problem, as reflected initially in the Packard-Bromley report on that subject, has grown to this day to the magnitude of about $12 billion, I think the latest estimate would be.

This is a huge problem. We had committed roughly $20 million in each of the past two fiscal years to try and address that problem, and in fact $40 million in awards are now going out the door to a variety of institutions to try and make what I would characterize as a very small dent in this problem. Now, much of the funding for most of these projects, in fact, has come from outside sources. The NSF's contribution has been relatively small.

The other side of the coin, however, is the instrumentation side. I think there is no question that if one wants to make a rapid injection into the research capability, especially of the individual researcher, that researcher, first of all, would choose every time to have his instrumentation. Secondly, I believe that over the long run, that also supports the Nation's infrastructure base by supporting the industries that manufacture that research instrumentation.

There are at least two very good reasons, the primary one of course being the up front support and the rapid injection of capability it gives to our research efforts, and secondly the subsidiary benefit, the spinoff benefit, if you will, of trying to enhance America's competitive position in the manufacture of important instrumentation. I should mention that's a position that has been rapidly eroded in recent years, and you can probably about guess from where that erosion has been coming. It is from Japan, of course, our friends in the Far East. I don't know whether Dr. Good would like to add anything to my remarks.

Dr. **Good**. Not a great deal. The need in terms of bricks and mortar is obvious. There is no question about that. The difficulty that we have is that the infrastructure requirements in science are not just bricks and mortar, however. People must have tools to work with. We, over the last five or six years, have not been able to provide those tools at the level that we should, particularly in the larger instrumentation areas. We have done reasonably well in small equipment grants.

But where you needed a piece of equipment today that cost a half a million to a million to a million and a half, and believe me, lots of the equipment today falls in that category, we have just not had the wherewithal to get that done. This new $50 million really allows us to do that for the first time in a long time.

I would simply like to echo Dr. Bernthal. It truly is just a matter of priority, because with a little over a $2 billion budget, a bricks and mortar problem, something significantly greater than that entire budget. We have to look at what we believe we can do, and do the most with the dollars that is reasonable. That's where we believe they should be.

Mr. **Boucher**. Acknowledging that we have a national need of about $12 billion for new bricks and mortar for research facilities, I think it is fair to say that no one would really expect the Federal Government to satisfy that entire need. Traditionally, the provision of those buildings has been more a State and local responsibility in any event. Only recently have we had a program in effect where the Federal Government made any contribution.

But making some contribution, to the mind of this member, at least, is important. I am wondering if we need to have an all or nothing approach here, where all of the money either goes to research facilities, or goes to what you define as a priority for instrumentation. Perhaps that $50 million could be divided between the two programs in some proportion. I wonder what your response would be to a proposal such as that?

Dr. **Bernthal**. My response would simply be that the judgment of the Administration was again, as I have said earlier, that the most effective use of this money, if you want to support the research efforts—and not just in the major universities, but also at two-year and four-year colleges, because they are eligible for these equipment grants as well—then that's really where the priority should be. In that particular area, $50 million will do a great deal of good, and do more immediate good than, let's say, putting half of that into bricks and mortar is likely to do.

I might also mention that it is not that this problem is being ignored, Mr. Chairman. It is just that we are looking at a $12 billion problem. One asks oneself how to most quickly benefit the research infrastructure of our country, and the decision, it seems to me, comes down clearly on the side of instrumentation.

It is not a problem that is being ignored, though. Dr. Bromley may in fact wish to speak to this issue in somewhat more detail. I understand he will be testifying before you this afternoon, I believe. He has looked at this problem very carefully, and I know the PCAST has been looking at it as well. He is certainly very sensitive to the problem and has been trying to take a broader approach, so that we are not just trying to throw a $20 million effort at a $12 billion problem.

I think that's probably the rationale that went into this decision, Mr. Chairman.

Mr. BOUCHER. Well, I thank you for your comments. I am sure that's a debate that we will continue to have for some several months.

Let me focus your attention on another area. The NSF, of course, is responsible for American activities in the Antarctic. I would welcome any comments that you have concerning the status of your efforts, particularly with regard to the regulation of the growing tourist industry there. I understand that to some extent tourism is now beginning to interface with, and perhaps interfere with, the research that is taking place.

What kinds of cooperative arrangements are you able to effectuate between the research entity and the tourism companies? To what extent are you now looking at a regulation of mineral extraction activities?

I understand some proposals have been made that we pass legislation in the Congress that would actually prohibit American companies, American entrepreneurs, from engaging in extraction activities. What discussions are you having with the private sector? What recommendations, if any, are you prepared to make to us on that front?

Generally speaking, I guess in the broad sense, how can we be of more help to you legislatively, in terms of your activities to regulate activities in the Antarctic?

Mr. WALKER. Mr. Chairman, Mr. Chairman?

Mr. BOUCHER. Yes, the gentleman is recognized.

Mr. WALKER. Could I add one more to that list? I have read recently that the SEI, the Space Exploration Initiative, is talking about using Antarctica as one of the places where they would do some training. Is that something that is being included in any of your programs?

Dr. BERNTHAL. Let me just respond broadly first to the issues that you raise. Then I would like to turn to Dr. Robert Corell, who is our assistant director specifically responsible for our Antarctic programs. All of the issue areas you mentioned are obviously very much on the mind of the Foundation.

We are responsible for the entire U.S. effort in Antarctica. And we are very sensitive to the environmental concerns down there. Congress made a special appropriation, a multi-million dollar appropriation designed to spread over five years to assist the Foundation in cleaning up some of the mistakes that have been made in the past.

I had the opportunity to visit Antarctica about two years ago. It was, I guess. Unless you have been there, it is difficult to appreciate the fact that pollution almost never goes away down there, and almost nothing else does, either, because of the extremely cold climate. In fact, a number of items that are left over from the days of early exploration down there can still be seen outside—some of the small huts built by the explorers in the early part of this century.

So the Foundation has been trying to do its part to clean up some of the residue of human activities left from years past. We are making good progress toward that. We are also undertaking an effort to install a new incineration facility there. We are more and more recycling materials as best we can in Antarctica.

We have also undertaken a special effort to try and communicate better with the environmental community. As a matter of fact, only two weeks ago, the Foundation held the fourth of its meetings where we invite representatives from all the major environmental groups in, explain to them what we are doing, and wherever possible, try to accommodate some of their special interests and inquiries and requests for—call it oversight, if you will, of our activities in Antarctica.

So that's one side of the coin, Mr. Chairman. The other side is the need, not just the desire, but the need, in many cases, to carry out scientific research in Antarctica. Those two objectives, preserving the environment and carrying out scientific research, don't have to be conflicting objectives. We simply have to learn to carry out that research in a way that is benign for the environment.

And in fact, much of the environmental research of Antarctica, much of the research in Antarctica, is environmental research, terribly important to our understanding of issues such as ozone depletion, the appearance of the ozone hole over Antarctica. It is very important to understanding how this tremendous heat sink in Antarctica drives world climate patterns, obviously important for our understanding of possible global climate change.

So we have two responsibilities here. One is to work with others, and work with the Congress in protecting the environment. The other is to see to it that legitimate scientific research can be carried out.

Tourism is becoming an increasing problem. I will just say that flatly and up front. We are increasingly finding that tourist ships, carrying loads of several hundred tourists and sightseers, are requesting to dock at our facilities in Antarctica. We had an accident near the Palmer Base on the Antarctic Peninsula—I should not say we did. Another country had an accident a couple of years ago which led to a significant—not a catastrophic—but a significant oil spill in that area.

So the requests continue to come. They not only pose a direct threat to the environment of Antarctica, but they also impose requirements on our logistics operations that we very often are unable to meet.

I might mention that in case anyone is feeling unhappy that they were turned down in one or another requests to visit Antarctica in recent months and years, we had to turn down two heads of state recently who had requested to visit Antarctica because we simply could not fit them into the required resupply flights and schedules. So tourism is an increasing problem, we are trying to deal with that as best we can, but I suspect that we will have to come up with some new, more systematic way to handle that difficulty.

I want to make one other short comment, then I will ask Bob Corell to fill in what I have left out here. As some of you here may know, you mentioned the mineral treaty, or at least the question of whether mineral mining would be permitted in Antarctica. That falls under the responsibility of the State Department.

There was a treaty negotiated, the Wellington Convention, I should say, a convention was negotiated a few years ago. That Convention has not yet been ratified by the Congress. That would have provided a system whereby a rather complicated — I won't say impossible—but a very complicated regulatory scheme was set up that would have kept very careful oversight on the part of the international community over any exploration and mining activities that might be undertaken in Antarctica.

Having spent five years on the Nuclear Regulatory Commission, I have some sense of a regulatory maze when I see one. I must say that I thought the Wellington Convention provided some very, very good protections for Antarctica and the Antarctic environment.

There are those who want to move beyond that now, and turn the Antarctic continent into an international wilderness park, if you will. That's an issue that I will leave to the Congress, but the National Science Foundation's interest in such questions touches again on our research responsibilities. Because if we lock up the Antarctic continent to the point where we can't carry out our research, then that clearly, I think, is not only a detriment to legitimate scientific pursuits, but probably a detriment to our understanding of the world's environment, as well.

Let me turn to Bob Corell and see whether he would like to add some detail here. Bob?

Dr. CORELL. Thank you very much, and thank you, Mr. Chairman. I will just add several other ingredients to this discussion.

First of all, some years ago the United States, through NSF, worked to establish what is known as the NMAP, the National Managers of Antarctic Programs. It brings together all of the countries' leaders who manage Antarctic programs for the purpose of dealing with a number of these joint issues: environment, tourism, and coordinated scientific research.

That body is now functioning. Peter Wilkniss, the Director of the Division of Polar Programs at NSF, has been providing major leadership to make that happen. Through that effort, we have been able to address, we think, some of these problems in a more coordinated way amongst all nations who participate in scientific research in the Antarctic.

It has been particularly visible in tourism, and it has been particularly visible in developing a leadership position with respect to environmental issues, so that the operations in the Antarctic are fully consistent with certainly United States regulation and law, in fact they go beyond those, and it provides an opportunity then to develop specific programs with specific countries to address specific problems. So NMAP is a very important vehicle by which we get these matters attended to.

Second of all, Mr. Walker's question about SEI, we have just in the last month signed a special memorandum of agreement between NSF and NASA to coordinate joint interests in the Antarctic, particularly in support of SEI, but other aspects of NASA and NSF's science agenda. Both Len Fisk and I have worked with our organizations to put that in place. That has been signed, programs are underway, and we will work directly with NASA in helping the SEI program develop.

Mr. BOUCHER. Thank you very much for that very thorough response. In the event that it would be helpful to the NSF in its management activities in the Antarctic to have additional opportunities through expanded legislative powers, I hope you will not hesitate to communicate that fact to us. We stand ready to help you in any way we can, in what I know must be a challenging, but very important, management activity.

Dr. Corell. Thank you very much.

Mr. Boucher. The Chair's time has expired. At this time I will recognize the gentleman from California, Mr. Packard.

Mr. Packard. Thank you.

Could you outline for us, Dr. Bernthal, the NSF's plans for implementing the Math Science Education Act that the President signed into law last year, how you plan to move forward with that? Particularly I am interested in the undergraduate programs.

Dr. Bernthal. Mr. Packard, let me go through just briefly what our efforts have been in that area. Then I may turn to Dr. Luther Williams here, who heads our Education and Human Resources Directorate for filling in the blanks that I may leave.

There were a number for programs which I will not enumerate that were specifically authorized in the Math and Sciences Education Act of 1990. Many of those programs overlap with existing Foundation programs, and let me enumerate at least in some of these areas what we are proposing to do in fiscal year 1992.

For example, in the development of innovative technologies, which of course would touch on precollege and certainly undergraduate education as well, new innovative methods, essentially, of carrying the message to students, if you will, our fiscal year 1992 authorization under that Act was $17.3 million. We have a $7.5 million request in that area.

For the establishment of science and technology centers in universities, there is no exact parallel to that effort, I think, as envisioned in the bill. I will let Dr. Williams explain exactly what we are proposing to do in that area, and the authorization there was for $33 million in the current fiscal year. We have a request that roughly totals $25 million in this general area.

In the systemic reform, the Statewide Systemic reform initiative that I mentioned earlier, my own feeling early on, after I joined the Foundation, was that that effort was significantly underfunded. The authorization request was for a little bit under $20 million, I believe, and we felt that was such an important effort, that the President has increased the budget request to $31 million for fiscal year 1992.

In graduate fellowships, another initiative area mentioned in that Act, the authorized level was $61 million. We are proposing to spend $50 million, fairly close to that authorized level.

Mr. Packard. Does that include undergraduate scholarships?

Dr. Bernthal. No. This is strictly the graduate fellowship arena, the NSF graduate fellowship program which is well known, and certain other areas as well.

Mr. Packard. Okay.

Dr. Bernthal. In women and minorities activities, Title IV activities, the authorized level was $47 million. We have a $50 million request in that arena.

We have been responsible in a number of areas, not every single area, however, has been proposed for funding in this particular year. For example, the graduate traineeships area, we have not—although we are carrying out a certain amount of traineeship effort, and we do have some traineeships, we will not be able to meet the higher proposed level of $20 million, which was authorized in that bill.

If I may turn, then, to Dr. Luther Williams, I would like him to add anything to that that he cares to.

Dr. **Williams**. Just several points. The increase for advanced educational technologies, which is consistent with one of the components of the bill, that 15 percent increase this year will primarily focus on networking school systems, school districts throughout the country, and teachers, focusing initially on the teachers who are awardees under the Presidential Excellence in Science and Math Teaching Award, both elementary and secondary, using those as a leadership unit.

The second area of the bill, to which Dr. Bernthal has already alluded, we have already initiated the Statewide Systemic Initiatives program, and are proposing to double the budget for it in fiscal year 1992, as a request. Systemic math and science education reform is underway. We have recently developed a five-year management plan to increase the stipend and cost of educational allowance for the graduate fellowship. Of course we will achieve doubling of the graduate scholarship.

And, as he indicated, our overall efforts for women and minority programs, actually for the fiscal year 1992 request, exceeds the amount indicated in the legislation.

The last item, the undergraduate program, it is true that we have not yet developed a program that would be sufficiently comprehensive to be an analog to what is referred to in the bill. We have, however, done two things. We have continued to increase the resources for faculty enhancement, making sure it is truly comprehensive to the two-year institutions as well as four-year institutions.

That has not always been the case. We have launched a major course and curriculum development venture, moving from the two previous activities that focused on calculus and engineering, to include all the sciences, all the mathematics and engineering taken in total. That's all the curriculum. Continuing with the Instrumentation and Laboratory Improvement program, with an addition this year that again requires linkages between two-year and four-year institutions, and the last component of it is continuing to support research to provide research experience for undergraduates.

In fact, on Friday of this week, we will have a conference in Washington in which we are convening leaders, presidents and vice-presidents from universities, to, among other things, consult with the directorate on the broad issue of a central approach to undergraduate education.

Mr. **Packard**. Along that line, what is NSF's plan regarding teacher education and teacher training?

Dr. **Bernthal**. Again, I think I will ask Dr. Williams to respond to that. This is a major priority of the Foundation, I should say, though, and we have two major new initiatives underway, at least two, that are designed to address this problem.

First of all, I would point to the State Systemic Initiative, which although it is generally focused on trying to promote precollege education, it meshes with our efforts in teacher preparation in the sense that that program, operated as it is, we hope, from the governors' level on down in the State, should be truly a systemic effort, so that in principle, that can also have its impact on teacher preparation and for those who teach precollege students.

We also have in the planning stages a rather similar effort. Both of these, by the way, are quite different from the way the National Science Foundation has tended to run our programs, generally, in education over the years. This new effort would be similar in broad philosophy and principle to the State Systemic Initiative in that it would consist of a very, very broadly worded request for proposals, but it would not be very specific, nor would we wait for the individual professor to come in with a small proposal.

Rather, a significant amount of money that an entire university, the chancellor, the president of the university could apply for, and try to explain to the satisfaction of the peer review system and the Foundation how the president or chancellor feels that the program he might propose can truly change, not only science and mathematics education generally in the colleges and universities, but also specifically the teacher preparation elements involved in that, we hope.

But let me turn to Dr. Williams and he can explain in more detail than I can what our programs are.

Dr. WILLIAMS. Thank you. Well, for reasons that are obvious, we regard teachers as core to the educational effort at the precollege level with respect to science and mathematics. Briefly, I would like to describe the four major efforts we have underway.

Number one is to deal with the competencies of those teachers who are already in the work force. If one attaches even minimum significance to progress toward achievement of the National goals, it is not clear that if not the, one of the great limiting events is the ability of the teachers to deliver quality instructions in precollege math and science.

So dealing with the competency, the contemporariness of the training, of the current teachers, is critical, and should be a first order of business. That has been targeted under our Teacher Enhancement program for the current fiscal year, with a significant increase from last year onto the efforts of the Congress, a nearly $80 million venture.

What we are doing is to a variety of programs throughout the country, addressing improving the preparation and the competencies of nearly 20,000 teachers. We have developed or nearly finished the development of a three-year plan to be consistent with the Congress' request for NSF's effort over three years. That's the first effort.

The second effort, beyond improving the preparation of the teachers who are already in the work force, and when I say teachers, I am referring to teachers in each sector: elementary science teachers; middle school math and science teachers; and high school math and science teachers. So the total system is being addressed.

The next is to train the next generation of teachers. There, we have a major effort in which we are going to ensure that the teachers are trained properly. What I mean by properly is that they are fundamentally grounded in science and mathematics. They learn the requisite pedagogy that relates to being a professional, and they obviously learn all the nuances and the practices of teaching as an integrated exercise.

We are revising our current program and basically challenging colleges and universities to create centers of math and science education, where there will be a composite faculty drawn from math and science and education, etc., operating in the unit. It is very important that these teachers be trained such that they have the benefit of the latest advances in the technologies to which were referred earlier, such that they do not need enhancement two years later. That is a major venture.

The third effort with respect to teachers beyond improving their preparations, is to leverage their leadership and their knowledge. The question is, how can one create a mechanism within a state, within a region, that is a network of teachers, in terms of leadership. What we are doing is using telecommunications to create networks of teachers, so that they can actually provide support systems for each other. They can exchange materials. There is some level of maintaining professionalism across a broader group of individuals.

Lastly, through our networks program, we are asking other players in the society, particularly from science and engineering industries, who are interested in K-12 education, who can in fact make contributions in an instructional mode, but should in fact do so under the general guidance of teachers to actually join networks with teachers, and become, if you will, adjunct work members of the K-12 instructional work force.

Dr. **Bernthal**. Mr. Packard, if you will indulge us for just a moment, Dr. Good would like to comment briefly on your question.

Mr. **Packard**. Please do, thank you.

Dr. **Good**. I would like to reassure you on a couple of issues. One is, I think, that because of the focus on research and that sort of thing, there is some concern that the National Science Board itself does not have some of these education issues as major, major thrusts. I would like to make a comment about that.

The Board today has organized itself in a couple of ways. One is that we only have two major committees today. One is the Programs Committee, which is essentially committed to the research programs across the Foundation. The other is the Committee on Education and Human Resources. That committee spends about half of the Board's time today, and half of the Board is assigned to that committee. The priorities there are very, very real, and the Board is extraordinarily interested and has a major concern that those priorities remain priorities.

One of those is in precollege education, which in a sense is a little bit new, or perhaps is more difficult in a way for us to do. The second one, which is perhaps the one we have neglected, is undergraduate education. If we look at this whole issue of how we get the best and the brightest back into these curricula, we have got to do something about the curricula. So the whole emphasis on undergraduate education - - I think you will see it in this budget. We are truly pressing to see that both of those priorities are maintained.

Mr. **Packard**. Thank you very much. I have other questions, but I will defer to my colleagues.

Thank you, Mr. Chairman.

Mr. BOUCHER. The gentleman's time is expired. The Chair now recognizes a former chairman of this subcommittee, the gentleman from Arkansas, Mr. Thornton.

Mr. THORNTON. Mr. Chairman, let me first express how pleased I am to have the privilege of serving on this subcommittee under your chairmanship. It is going to be an exciting time, and I am looking forward to this opportunity.

Also, at the risk of some nostalgia, I should like to add a further element of appreciation to the witnesses. It is good to see you again, Dr. Bernthal. Dr. Good, is it all right if I reveal to these people here that we claim you as an Arkansas citizen?

Dr. GOOD. That's okay.

Mr. THORNTON. Dr. Good's sister, Dr. Betty Lowe, is the dynamo behind the Children's Hospital in Little Rock, which is one of the premier institutions in a non-major city setting anywhere. And I must also say—well, I could call the roll. Karl Willenbrock and—I want you all to know that I tried to get Luther Williams to be the Dean of Arts and Sciences at Arkansas State University and then tried to get him to be a chancellor of one of the campuses at the University of Arkansas. I could not find a way of working with him except to try to run for Congress so I could have the privilege of coming back.

[Laughter.]

Mr. THORNTON. But I am not here to engage in nostalgia, but to commend you for the vision that this report and recommendation indicates and to ask that you stretch beyond this report to giving us, either now, or at some other time more appropriate, a vision of what could be done in the best possible world to address the problem of declining American competitiveness in the world economy.

For some months now, I have been suggesting that with the end of the Cold War, and this war in the Gulf will end, and I for one am not going to be interested in developing a program to rebuild Iraq, but rather for months now have been calling for a Marshall plan for America. I think we should do for our country now what we did for Europe and Asia at the end of World War II, when we recognized that their infrastructure was destroyed, that the safety and security of the world depended on rebuilding institutions there, and in a magnificent, and self-serving as well as altruistic gesture, we developed a well thought out strategy and plan for rebuilding our former adversaries and allies.

I think we have a significant opportunity today to develop those same strategies for America, not only rebuilding infrastructures of roads, highways and bridges, and developing energy independence—all of those are important—but also to rebuild the scientific infrastructure and concentrate upon the linkages of scientific genius to competitiveness.

In order to do that, what kind of base do we need to develop? Do we need to strengthen not only the apex of our scientific research programs, but also to expand the base of knowledge, throughout the United States? I am most impressed with the increases in education and human resources, the programs that are being developed for minorities.

I think you all know I am interested in the continued progress of the EPSCoR program. But how could you relate, briefly, right now, to the concept that I am bringing forward, and would it be possible for you to work with this committee in developing a plan as to the role science could play in a Marshall plan for America?

Dr. **Good**. I would love nothing better than to do that. I think that's a challenge that we don't get very often. And I think the National Science Board is a vehicle that could help in that. I think they would be delighted to be challenged to do just that. The Foundation is certainly doing that, but perhaps not in some ways with the vision that you have in mind. And we would be more than happy to come back, if the committee would like for us to, and put some horses behind such a study and see what we could do in that context.

If I were to look at it today, I suspect that the thing that is going to come back—and I think most of you already would envision it—is really two-fold. One is the whole education issue simply must be addressed in some visionary, holistic way, rather than in bits and pieces. It is very difficult to do that, but there is that issue. And the fact that we have major technology today which we use in lots of things, but we do not use it in education, I think that issue was brought up earlier, that our whole ability to use the technology we have in education is not there. Those are some of the kinds of things you are talking about, I think.

I think the other part of it, in terms of science, is the issue of essentially empowering people to participate in science. One of our big problems, I think, is the fact that the technology literacy of the country is extraordinarily poor. If you go around and talk to children, even with television such as we know today, and all the computer games that there are, there still is a scientific and technological illiteracy which is just overwhelming. Somehow to get at that — because people must understand the infrastructure if they are going to participate.

So the whole issue of education I suspect is a big piece of it. The other issue is how to harness what we know how to do. I am not one of those who believes that the United States is on its last legs and without talent and that it does not have what is required to be competitive. We need to turn people loose again. We need to have some people feel they can make a difference. How you do that, I am not too sure. But I would be delighted to turn the Board loose to see what we can do with your quest.

Mr. **Thornton**. Of course, I did not mean to suggest that the committee might want to explore that, but I personally would very much like to explore it, and using a figure, I have felt that the United States economy and free enterprise system might be a little like Gulliver tied down on the beach at Lilliput by thousands of threads, and that we might give some appropriate attention to how to improve upon the ability of the American economy to be competitive throughout the world.

Yes, sir?

Dr. **Bernthal**. Yes, Mr. Thornton. First of all, welcome back. I should mention to you, while I have the opportunity, this may be the first time that you have had two Arkansans sitting at the table here. The gentleman to my left is also an Arkansan, John White. I don't know if you were aware of that.

Mr. **Thornton**. Yes, sir.

Mr. **White**. Had Dr. Bernthal not done that, I would have had to stand to be counted, lest my parents think that I did not stand up when someone said "Arkansas."

[Laughter.]

Mr. **White**. They have retired recently with over 70 years of service in the public school system in Arkansas. They retired in Crossett, Arkansas. And I am a graduate of the University of Arkansas.

Mr. **Thornton**. A splendid institution.

[Laughter.]

Mr. **White**. Now, having stood and been counted, I would like to return to this issue, if I may, to touch on some things that are going on in the FCCSET process, and also what we are doing at the National Science Foundation with respect to the technology issue.

Dr. Bernthal?

Dr. **Bernthal**. Let me just comment very broadly so we don't take too much time on this issue. First of all, the Foundation and the Board as well, as Dr. Good has indicated, would be delighted to work with the committee along the lines you have suggested.

I want to mention one or two things, however, that at least might provide some indication of the directions the Foundation has been taking throughout the decade of the 1980s. Vannevar Bush, who might be called the godfather of the National Science Foundation, and certainly of this country's post-World War II science and technology policy, wrote a seminal treatise on the subject, as you well know, entitled "Science: The Endless Frontier." It has become something of a bible for those who wish to go back and find out how we got where we are today.

The interesting point about that book is that Vannevar Bush envisioned, in fact, that a technology policy would be an integral element of the U.S. Government's efforts. That portion of his vision, the technology activities that he thought would be married with science, never really materialized in the National Science Foundation through the first three decades, more or less, of its existence.

Now, it must be said here that Erich Bloch, the previous director of the Foundation, who finished the first six year term, by the way, since Harry Truman's appointee, just last August, he had a vision along these lines. That vision was to try and develop a kind of technology policy, if you will, for the National Science Foundation that fits within the rather narrow confines of existing U.S. Government technology policy.

It is not clear exactly what the American people want, what U.S. industry wants, and certainly not what the Government reflecting those interests really wants this country's technology policy to be. But what Eric correctly saw, I think, was that the thing the Foundation could do is play to the strengths that the U.S. has. That strength is most notably the very strong research base that we have in our university system. That is the thing the United States of America has that no other country can match.

So through the efforts of Science and Technology Centers, Engineering Research Centers, Industry-University Cooperative Research Centers, soon to be expanded, as someone has mentioned earlier here, to involve the states, there was a major effort begun under the National Science Foundation within the last few years to begin to address the very question that you are raising here. So the effort has begun. I think a great deal more can be done, and we certainly intend to continue those efforts in the Foundation.

Mr. THORNTON. Thank you, Mr. Chairman.

Mr. BOUCHER. The Chair thanks the gentleman and the Chair would note that the recommendation of the gentleman from Arkansas that there be a study on a domestic Marshall plan for the U.S. and the role of the National Science Foundation in that is very welcome. Of course, we will have to coordinate our efforts with our friend from North Carolina, Mr. Valentine, and this subcommittee's companion Subcommittee on Technology and Competitiveness. But I think it is an excellent idea. We will put that on the list of items we will undertake as a subcommittee during the course of this Congress.

I might take the opportunity to say to the members that we would very much welcome any thoughts and suggestions others might care to make about items we should undertake, either by way of hearings or legislation. It is the Chair's intent to compile and distribute a preliminary agenda for the 102nd Congress within the course of the coming two weeks that will be comprised of recommendations we have received to date. That will be an open agenda, which will be subject to edition, as members of the subcommittee make recommendations to us throughout the course of this Congress.

So I thank the gentleman from Arkansas for that suggestion, and would very much welcome other suggestions from other members.

The Chair recognizes the gentleman from Illinois, Mr. Fawell.

Mr. FAWELL. Thank you, Mr. Chairman.

Dr. Good, when you just made reference to general illiteracy in many of our students, and I would agree with you in that regard, I could not help but recall—and I think I have a copy of the column which I believe came from the Chicago Tribune, which interestingly referred to a poll of citizens in this country and in Japan, in regard to science literacy.

Lo and behold, we won. The general citizen of this country, according to this particularly poll, actually was more literate and answered the questions with a higher score than did the Japanese. I thought I would just mention that. It is one of the few bright lights I have seen for quite some time.

Dr. GOOD. Right.

Mr. FAWELL. But my question, which would be directed both to you and Dr. Bernthal is this. About a week ago I had — we have an education advisory committee, also a science and technology advisory committee, although I am one of those lawyers you made some reference to. There are lawyers all over Congress. I am an escapee from liberal arts, bouncing around in science.

Several high school physics teachers testified, one Lee Merrick, who teaches physics at Neighborville North High School in Illinois, and has received many awards for what he calls "weird science" with all the bells and whistles, which is done to interest young people in what physics is all about, and science. He made the statement that in the last 1960s and early 1970s the National Science Foundation did have a scholarship program for middle school and high school teachers in the science area, to be able to get graduate work, a master's degree, and summer scholarships, and I think night school.

He and another very successful physics teacher, from Hinsdale High School, also went along with his comments. Both of them had gotten their graduate work through NSF. They had pointed out that this had been discontinued.

They felt that this was a tremendously successful program and that the need for high school teachers to be able to get additional substantive science courses, not how to teach or educational courses, necessarily, those seem to abound, if I am correct in summarizing their testimony, but they had nothing but praise for the NSF program back in the 1960s and early 1970s.

They pointed out that each of them were able to go ahead in their physics program, and they have become renowned in our area, working with both Fermilab and with Argonne. In our particular area, we are blessed with having an abundance of talented people in the science, math and engineering fields.

But they pointed out that downstate in Illinois and in many other areas, the chemistry teacher is the one who has to handle the physics course, and things of this sort. They asked if I would undertake a review of this, and lo and behold, I noticed that this hearing was to be held. There have been all kinds of references to the precollege emphasis, although I am not clear in my own mind which particular portions of the budget might be a basis for this.

But I would like to have you comment on this. They were so laudatory of this program. They said you could do nothing better to help the beleaguered high school and middle school teachers to give substantive quality to the students and to reinstitute this program. I would like to have your comments on that.

Dr. BERNTHAL. I am told by some of those who know the history better than I do here that what you are referring to, I am sure, Mr. Congressman, is the NSF Summer Institutes program. We have many summer institutes that continue, but in this particular program, I am told that teachers were able to derive graduate credit from those summer institutes. I am going to ask Dr. Good—

Mr. FAWELL. I gather they had a stipend, some living expenses, and room and board and they swear by it.

Dr. BERNTHAL. Yes.

Dr. WILLIAMS. Congressman, Dr. Bernthal's explanation is exactly what the physics teachers with whom you were consulting were referring to. In the 1960s and 1970s NSF ran what is probably fair to say a rather substantial collection of summer institutes. They were all over our college institutes and campuses. They were for middle and high school science and math teachers. By definition they took substantive courses in math and science, and obviously those courses, upon their passing them, would apply toward graduate credit.

One of the really interesting outcomes from that era was that an awful lot of K-12 middle and high school teachers left the system because they got graduate master's degrees in physics, and many of them actually got doctorate degrees in physics.

But many of them remained in the system. That is what is being referred to. It made provision, as you said, for a stipend, living expenses, etc. When I was talking about the Teacher Enhancement program, that's exactly what it is. It is summer institutes, by another name. Those programs are also on college and university campuses.

The issue really is the magnitude of the program. It is nowhere near what it was in the 1970s and 1980s. But we run such programs currently, including two at Fermilab, to which you refer.

Mr. **Fawell**. Could you—not necessarily now, but if I could be supplied with the extent of the program, how much money is being set aside for it?

Dr. **Williams**. Surely. I would be pleased to do that.

[Information requested by Mr. Fawell follows:]

INFORMATION REQUESTED BY CONGRESSMAN FAWELL ON NSF TEACHER ENHANCEMENT PROGRAM

In FY 1990, NSF's Directorate for Education and Human Resources supported 411 Teacher Enhancement projects throughout the United States and its territories. On an annualized basis, EHR funding to support these projects during fiscal 1990 was approximately $39,700,000.

Compared with the Teacher Institutes of the 1960's, current projects tend to be smaller in size, larger in number, and geographically more distributed. Today's projects also cover a broader spectrum of educational levels, with equal emphasis now placed on preparing K-8 science and mathematics teachers; the Teacher Institutes were focused almost exclusively at the secondary level.

Although many Teacher Enhancement projects of recent years do offer graduate credit, few such projects lead directly toward a graduate degree. The FY 1992 guidelines for NSF's Teacher Enhancement Program will place more emphasis on projects that assist precollege teachers in attaining a graduate degree.

To publicize these projects NSF annually publishes and disseminates a "Directory of NSF-Supported Teacher Enhancement Projects".

Mr. **Fawell**. I write a weekly column in my district, too, and I would like to give some publicity to this, and bring out that it does exist.

Dr. **Williams**. Yes.

Mr. **Fawell**. I would like to communicate with our elementary and secondary schools in the district and let them know that this is a very real possibility. Most high school teachers don't have a great deal of money to pursue their graduate education.

Thank you very much.

Dr. **Williams**. I would be pleased to do that, right away.

Mr. **Boucher**. The gentleman's time is expired. The Chair now recognizes the gentleman from Indiana, Mr. Roemer.

Mr. **Roemer**. Thank you, Mr. Chairman. I appreciate that. I too am very excited about your new chairmanship and serving with on discovering some new potentials and possibilities in this committee. I also applaud the former chairman here for his very wise and prudent remarks. I would like to echo many of those in what I hope is a brief comment here.

I would also like to say that since my colleague claimed so much association to Arkansas, I would at least like to make at least a temporary claim to Dr. Williams, who served at Purdue University in my Hoosier State for a while, and claim some of the expertise on that very distinguished panel.

Is that okay with you, Ray?

[Laughter.]

Mr. **Roemer**. Good. As we all talk about this Marshall plan, and rebuilding in this country, and the tasks we have ahead of us, I recently read a book by Mr. Kennedy on the decline of great nations. I, for one, am not one of these people that thinks this country has seen its best days. That's one of the reasons I ran for Congress, that is that I am not going to bring up the next generation in an environment that does not give them the opportunity and the hope and the chance of more success than we have achieved in my generation or that my parents had.

You people are a big key to where we go and how that opportunity will be passed down to successive generations. I just had a week last week with my education committee assignment and this assignment where I spent much time in the schools, and much time with businesses. Everybody back in my state is very cognizant of the problem that we have, but willing to spend time on solutions to that problem.

I had an individual meeting. I have town meetings as well, but I have people come in and talk about what they see are the biggest problems we face, a week and a half ago. Nobody mentioned the Persian Gulf. Forty percent of them mentioned education. It was astounding to me, and to us on our staff. I think that gives us hope.

I guess one of the things I would also like to brag about is the Christa McAuliffe Award, that was recently given to one of the teachers in the Third District of Indiana, at Penn High School, where I went to high school. This award recognizes her achievement in working with technology, specifically communications technology.

I would like to ask a question about this, and maybe Dr. Williams can refer to this as well. How do we continue to encourage our teachers, especially in the K-12 level, to work with new, innovative technologies, and science and environmental education? How do we reward them, encourage these new generations of teachers to get involved, and are magnet schools a possibility in this area as well, too?

Secondly, Dr. Good, with your comments on the State Industry-University Cooperative Research Centers, and how we are trying to get local development with local economies and technologies. I would like you also to comment on that. I have a couple of universities and businesses that are now formulating partnerships, trying to work together on the ground in those areas. I am very excited about those possibilities, but if you could comment on those two areas, I would appreciate it.

Dr. BERNTHAL. Mr. Roemer, I would like a couple of our people to comment specifically on the technology issue you raise. I want to point to the High Performance Computing Initiative, because part of that initiative, in fact, is designed to support the very technologies you are talking about. We expect that the advances in that area could in fact revolutionize the way we teach in this country, and particularly the way we teach science, mathematics and engineering, at the preschool level as well, but certainly at the precollege level and undergraduate education especially.

The promise of such technologies is that they will not only benefit the institutions that are well endowed, either by virtue of state funding or by private funding, but the many, many institutions that may not right now have access in remote locations, outlying areas, to the kinds of first-rate equipment, for example, that can demonstrate laboratory procedures, or simply do not have access to all the personnel they might want.

But I would like for Dr. Chuck Brownstein to elaborate for just a moment on exactly what is happening in that very important High Performance Computing Initiative area, and then Dr. Williams, as well, to explain how we hope to transfer that into practicality.

Dr. BROWNSTEIN. Thank you.

Mr. ROEMER. Where are you from?

[Laughter.]

Dr. BROWNSTEIN. I am Charles Brownstein, the Acting Assistant Director for the Directorate for Computer and Information Science and Engineering at—

Mr. ROEMER. He's not from Indiana.

Dr. BROWNSTEIN. I have been to Indiana and Arkansas.

[Laughter.]

Mr. ROEMER. I don't want to get too parochial here.

Dr. BROWNSTEIN. I enjoyed them immensely.

I should tell you, although I have not been there recently, that the NSFNET goes to both of those places, and that the researchers in your universities have access to not just their colleagues nearby, but to facilities all over the United States. That include things like supercomputer centers, and also instruments like arrays of radiotelescopes, and in the future, other things as well. That development has occurred because of the development of NSFNET.

Building on that, the entire Government has joined in this initiative in High Performance Computing, to integrate a variety of networks that exist to give truly unprecedented opportunities for

American scientists to have access not just to resources like supercomputers, but to each other, which is very important.

One major part of the effort is making sure that that infrastructure is easy to use and highly accessible, also, for education. While there has only just started an effort to get beyond the research institutions and major laboratories of the country, we have been quite successful. One hundred undergraduate institutions were added last year, at the end of the fiscal year, and probably another 100 will be added this year. Within two or three years, virtually all undergraduate institutions will have access to this network.

We have begun putting high schools on the network. Science and technology high schools have been the leaders, through participation in things like the SuperQuest competition that was run at Cornell University last year. But we have a partnership with all of the disciplines to have them provide the content that people use over this network. So we are focusing on the infrastructure.

For example, with the Engineering and Human Resources Directorate, we have embarked on a plan to begin systematically to involve high schools in using this network. The ability to do that is hard won, in the sense that we have to move through research, from very expensive technology, and somewhat arcane and difficult to use technology as your staff has probably learned, to use that network well, to where that is simple, transparent, easy for anyone to use, and inexpensive for high schools to connect.

We are, through the research programs of the High Performance Computing Initiative, coming very close to that. High schools can now get dial-up service for as little as a couple of thousand dollars a year now. That price is going to come down very dramatically as the cost of the technology comes down.

By the same token, what is in this initiative is focused on higher performance computing. You think of supercomputers. But the keystone to this thing is that it is not supercomputers. It is high performing computers that are scaleable, so that the same technology appears in the most advanced supercomputers and the machines on your desk. That will give the supercomputing industry a real basis in the economy to stay competitive, rather than building very special, very single-minded sorts of devices. And it will make the same technology available for everyone from the high schools to the most advanced labs, as part of the initiative.

I can provide you all with—

Mr. ROEMER. I would like to see it.

[Information requested by Mr. Roemer follows:]

The Foundation is nearing completion of its report describing plans for enabling widespread use of networking in precollege science and mathematics education. I shall be sure that copies are sent to the Committee as soon as they become available.

Mr. ROEMER. I would just like to comment, too, on your efforts to get the teachers networking together. Elizabeth Barrett, the teacher that received this award at Penn High School, was so excited about the possibility of getting together at Stanford with other people that received these awards, sharing their ideas, then coming back to the district and trying to promote those and promulgate those to other high school teachers in our area.

I think that opportunity to provide leadership and a networking for those people is so critical. It is very, very important.

Dr. **Brownstein**. Our experience is that the leaders provide the leadership. We can provide the infrastructure and a system to do that. But like your use of the telephone, no one out there could imagine what you would do with it. I think we are at the takeoff point for education with this kind of infrastructure.

Dr. **Bernthal**. Mr. Roemer, if we can respond now quickly to one other issue you raise, that's in the University- Industry Cooperative Research Centers, I would just say that that has been one of the notable successes of the Foundation in trying to address this issue that Mr. Thornton and others have raised, the issue of competitiveness. It has been highly leveraged with industry participation. We now have 45 such industry-university centers, and then taking off on that effort, have set up a pilot program to involve the states specifically in similar centers. Dr. John White, through his Engineering Directorate, has been eminently involved in that. I would ask him to comment briefly on it.

Mr. **White**. You, I think, are very familiar with the IUCRC, certainly in Indiana. I jus met this morning with the panel that is looking at the state IUCRCs. That, by the way, was an outgrowth of a joint effort with the National Governors' Association.

About three weeks ago, I had an occasion to talk with your Governor about the situation. He certainly understands the kind of role we want to play with respect to technology. These centers are unbelievable in terms of their attraction to industry. Roughly, we put in eight percent of the funds, if you can believe that kind of leverage. It comes largely from industry, like in 1990, we had roughly $4 million in the program.

We got $23 million coming in from over 400 corporations nationally, about $18 million from states and universities, and $5 million from other Federal agencies. We actually had more money coming into this from other Federal agencies than we were putting into it.

The new twist on that, working with the states, is very interesting, because it is an equal partnership between the state, between industry and NSF, dollar for dollar. We will put in up to $250,000. It has to be equally matched by the state with new money that goes into that center, and from industry. It is in fact a new way of evaluating them. We do a two-tiered evaluation. The first tier is on the basis of the quality of the research. In fact, that is what the panel is addressing today, that I met with this morning.

The second is economic development in the region. We are trying to bring those together in a way that both you and Mr. Thornton have articulated. So I think you should at least be aware of those programs, that we are trying to make a start with it this year.

Mr. **Roemer**. Who would I contact, Dr. White? Would it be you, to find out more information on this?

Mr. **White**. You can certainly contact me, or Dr. Ray Bowen, who is the Acting Assistant Director for Engineering at the Foundation. Either one of us would be pleased to respond to your request for information.

Mr. **Roemer**. Thank you. Dr. Williams?

Dr. **Williams**. I would like to make three additions to Dr. Brownstein's comments. Not only are we working on the network, and developing that capability. Another critical issue, obviously, is to employ the technologies in the educational mode. We have a grants program, and this request is for about $8 million, in which we support the development of a variety of instructional formats that would be available throughout the country. I wanted to emphasize that.

Second, I agree with you, there is some merit in actually focusing on magnet schools, science and technology magnet schools. In fact, the way in which I regard them is that there is a possibility they could become regional resources, that served an area. There are several such high schools in a state, and they might in fact be the development, the leadership units, for the teachers who are in nonmagnet schools.

The point of those comments is that we are trying to deal with the broad question of telecommunication-based access, developing curricular materials to take advantage of the very latest technologies, and second, continuing to look for ways in which to have that work on a nationwide basis. The fundamental problem, as I view it, is that in state X you need that requisite capability locally. One way to do it would be to focus on science and technology schools.

Mr. ROEMER. Thank you. Thank you, Mr. Chairman.

Mr. BOUCHER. I thank the gentleman. The gentleman's time is expired.

The Chair understands that the gentlewoman from Michigan, Mrs. Collins, may have to depart, so with the indulgence of the gentleman from Maryland, Mr. Gilchrest, the Chair will recognize Mrs. Collins at this time.

Mrs. COLLINS. Thank you very much, Mr. Chairman. I too would like to say how excited I am to serve on this subcommittee. I knew it would be very interesting. I did not know how vitally important this subcommittee will be to the educational quality of our country.

I want to make one comment. That is to suggest, Dr. Bernthal, that NSF consider teacher initiatives in the elementary level. I did serve on the school board for three years in the City of Detroit, and I find that by the time the students reach intermediate school, they have already become disenchanted with science and with mathematics, and that it is something we really need to zero in on at the preschool level, if possible, to let the students know how exciting it could be.

I want to go back to the Antarctic.

Dr. BERNTHAL. Me too.

[Laughter.]

Mrs. COLLINS. Actually, I don't want to visit. We have cold enough winters in Michigan. But you mentioned in passing that you are building an incinerator to try to get rid of the debris, the trash, from previous research facilities. I wonder what would be the effect of that incinerator on the ozone hole, the pollution, and you mentioned that pollution never goes away. What would be the effect of an incinerator?

Dr. BERNTHAL. That's a very good question. My mere mention of an incinerator, I guess, appropriately conjures up images of smoke plumes and our very own smog bank on the pristine Antarctic continent. I can assure you that is not the kind of incinerator we are proposing to build. Let me ask Bob Corell to elaborate.

Dr. **Corell**. Thank you very much. We have hired several consulting firms, engineering consulting firms, working with our Antarctic contractor to look very carefully at the whole issue of waste. Part of the program is to not take it there in the first place, so that we don't have to then dispose of it. So there is a great program to package our materials as they go down in an environmentally responsible way.

There is inevitably the need to incinerate or to in some fashion remove some of the waste materials that have to be taken to the Antarctic. Our first position is to try to retrograde, bring it back home, like the hikers of the Appalachian Trail or the Muir Trail. What you take in, you take back out.

But some of that is just economically impossible. So we are in the middle of very careful assessment of waste removal from the Antarctic. Some of it may in fact end up in an environmentally safe incineration system, much like a number of our cities have had to go do in this country.

But we have not completed these studies, so I can't give you a fully definitive answer. But we would be delighted to supply it to you if you would like to have the results of our current studies at this time.

Mrs. **Collins**. I do know a little bit about the new incinerators, recycling incinerators. But they have not seemed to have met the requirements, the EPA requirements for mercury and those kinds of things. So I would like to get more information.

Dr. **Corell**. Surely.

[Information requested by Congresswoman Collins follows:]

INFORMATION REQUESTED BY CONGRESSWOMAN COLLINS ON AN ENVIRONMENTALLY SAFE INCINERATION SYSTEM AT MCMURDO STATION

To eliminate the current practice of open burning in the Antarctic, NSF will install an incinerator at McMurdo Station during the next austral summer season.

This incinerator, identical to a model utilized by other government agencies in a variety of locations, would meet the same environmental standards required in the U.S. It will be used primarily for food waste and food contaminated products.

The primary sources of heavy metals in the waste stream will not be incinerated. Hazardous materials, including items such as old batteries and solvents, are returned to the U.S. for disposal in accordance with U.S. law. Much other refuse, which might be burned in a municipal incinerator in the U.S., will be shipped back from McMurdo for recycling. This includes items such as cardboard, "tin" cans, glassware and office waste, and is an expansion of a recycling program initiated at McMurdo in 1989.

Mrs. COLLINS. And my second question would be, now we are very much aware of pollution in the Antarctic. What about the foreign research facilities? Do we have an control over them? Is it a cooperative type of thing? Are they answerable only to their own country as far as debris and trash and pollution?

Dr. BERNTHAL. Let me again ask Dr. Corell to respond in detail. The short answer to your question, however, is that each country is ultimately responsible for its own activities, under the terms, however, of the Antarctic Treaty, to which I believe there are 21, or something like that, countries that are signatories.

We cooperate rather closely with a number of other countries in specific research projects. The severity of the climate and environment in Antarctica often requires that we lend assistance in a variety of ways to other countries in tactical matters, logistics, but also in assisting them in research efforts.

But the short answer is that there is no umbrella research agreement for which the Foundation is responsible in Antarctica. A lot of cooperation, but in the end, each country is responsible for its own activities.

Mrs. COLLINS. Very briefly, then, would it do any good for us to have a cleanup campaign in the Antarctic, and the other countries go right along polluting?

Dr. CORELL. Thank you. That affords me the opportunity to talk about what we call our Safety, Environment and Health Initiative, which began in fiscal year 1990. It is a major effort on the part of the United States to demonstrate leadership in the Antarctic for cleanup of Antarctic environmental issues, for being certain that we can operate safely year-round, and to deal with some of the health issues that are paramount in our field parties, and the locations in the Antarctic.

It was started in fiscal year 1990. It is a five-year effort. Our goal is to clean up any past environmental debris that has been left from previous operations over the last 30 or more years, to bring our operations in full compliance with current regulations in the United States, and in effect provide international leadership by demonstrating that we can operate in the Antarctic in an environmentally responsible way.

The Antarctic explorations began, and the IGY, in the late 1950s. It was very difficult in those days, and I think to some extent we did not have the environmental consciousness that we have as a Nation today. So we did leave things that we need now to bring into accord with current practice in this country. This initiative, funded at a very substantial level over those five years, will enable us to do that.

We are in fiscal year 1992, the third year. That program is fully on track and meeting the goals and objectives that were set forth three years ago. There is a document and a plan, and we will see that you get a copy of it so you fully get its background and the details of what it is we are doing.

Mrs. COLLINS. What is the name of that?

Dr. CORELL. It is called the Safety Environment and Health Initiative, SEH.

Mrs. COLLINS. And what is your name?

Dr. **Corell**. I am Bob Corell, the Assistant Director for the Geosciences, within which the U.S. Antarctic program is housed.

Dr. **Bernthal**. Mrs. Collins, I was not sure whether you wanted to discuss the issue of grade school, and elementary school teaching further.

Mrs. **Collins**. No, I do not. At the last hearing with NASA, with the full committee, I mentioned the fact that we were losing an awful lot of perhaps future geniuses because of their loss at the elementary level. I just wanted to make the statement, and not discuss it. You can just think about it, and if you already have programs you can perhaps let me know.

Dr. **Bernthal**. We do have programs. I will just comment for half a minute. You are exactly on point, though. Most of the indicators we have, and I won't say these are hard data, but the indications seem to be that we lose these children to science, mathematics and engineering somewhere between grades five and ten. Some would argue even before grade five. We have a terrible problem in that respect, and it is something that we are trying very hard to address.

Mr. **Boucher**. The gentlewoman's time is expired. The Chair recognizes the gentleman from Maryland, Mr. Gilchrest.

Mr. **Gilchrest**. Thank you, Mr. Chairman. I would like to reemphasize the elementary school. As a high school teacher, when these youngsters come into high school, a lot of them have forgotten about education years earlier. So the excitement has to take place in the elementary school.

That sense of curiosity is so important for people considering what they want to do. Kids are like adults, if they don't have any sense of curiosity, then they are pretty much dead in the water. I think maybe we are a little bit ahead of the Japanese insofar as terminology, because we watched Star Trek. I know my children do. It's Star Trek: The Next Generation now. Whether that's good or bad, I don't know. But it certainly is out there.

If I may, in my humble sense, I would like to make two recommendations, which I have tried to implement as a school teacher and have not been successful. The source of information that students have are the textbooks. Very often, unfortunately, the textbooks are not very interesting, and do not have a tendency to stimulate curiosity. I think if you focus in on the types of tools teachers use in the classroom, and try to enhance the quality of the textbook, that would be, in my estimation, a pretty major step toward achieving some of these goals.

One of the textbooks I would like to recommend is a book I read about 20 years ago, which might want to be updated, I suppose. It is called The Ascent of Man, by Jacob Bronowski. It is an excellent introduction into the science world, and engendered in this textbook is not only science, but philosophy, history and the things people need to know about their world and human nature. So that type of textbook, in a classroom, probably would need to be at a high school level, could really stimulate a lot of activity.

The other thing I have tried to do as a school teacher and have not been successful, is require National Geographic as a textbook. Perhaps it would be useful in a middle school. This bit of information, each student could be given one a month, and that would be that student's text. That covers in enormous weight things that deal with the scientific field, but in a way that could engender that requirement, which is curiosity. I just thought I would throw that out.

My question does not deal necessarily with education, but with global change or global warming. I would just like to know where we are now as a species and a planet in the solar system as far as climate change, the cause of climate change, in your opinion, the research into slowing that down, and what efforts or research is your organization doing as far as fusion is concerned, and is fusion ever going to be a possibility?

Dr. BERNTHAL. There are two questions. Let me dispose, if I may use that word, of the second one first. In the fusion energy area, we carry out, or sponsor, I should say, fundamental research in respect to plasma physics, for example. But we are not involved in the development efforts to achieve a working thermonuclear reactor. That is in the Department of Energy.

So the fundamentals, certainly, the fundamental research on plasma physics, or at least some portion of that, a relatively small portion I should say, is carried out under the auspices of our Physics Division. But the lion's share of that program and that responsibility, particularly the application of fusion physics and the possibility of thermonuclear reactors, that is in the Department of Energy.

On the climate change front, I can talk longer than any of you would care to listen. Because I was involved very much in the international efforts in that area, and chaired the third so-called Response Strategies Working Group of the Intergovernmental Panel on Climate Change, which ultimately led to the beginning of negotiation on a climate change convention as you probably have read out here in Chantilly just two weeks ago, at the invitation of President Bush.

You have asked a question about the science, though, and although I have my own opinions, and meteorology actually was my first love in science, I am going to turn to someone who is more expert than I am on exactly where we are in the science field these days, and again ask Dr. Robert Corell, who funds a significant, major portion of the Federal Government's efforts in climate change research through his Geosciences Directorate.

Dr. CORELL. Thank you very much. During the past couple of years, year and a half, in parallel with the committee working group that Dr. Bernthal chaired, there was a major assessment of the state of science in global climate change throughout the world. Many hundreds of scientists participated and produced a consensus document of the state of knowledge and the state of understanding of global climate change as we see it today.

That document, which we will be pleased to provide you, will give you some sense of the consensus within the international scientific community of the state of knowledge, what we see coming in the future. It indicates such things as, during the past 100 years, there has been on the average around the globe a warming of between one half and one degree centigrade. That is not in doubt, and there is a projection that that will continue.

What is in doubt is its origin. What causes it? Is it a natural variability that is occurring frequently over time, or whether it is anthropogenic in origin? I think you will find this report, both its executive summary and the full document, very readable, and it will give you some insight into a whole series of scientific findings, if you will, that underpin the world's opinion and the scientific community's assessment. We will see that you get a copy of that.

Mr. GILCHREST. Thank you, Mr. Chairman.

Mr. BOUCHER. The Chair thanks the gentleman, and recognizes the gentleman from Kentucky, Mr. Perkins.

Mr. PERKINS. I want to thank the Chairman. I would like to first of all congratulate the Chairman on beginning a new term as subcommittee chairman here. I am sure he is going to do a wonderful job. It is always to have my neighbor—he lives only three counties away from me—so it is a wonderful thing, indeed, to have Mr. Boucher, who has a great deal of interest in this area, and has previous service with me on Education and Labor, and has shown a lot of interest in this area.

First of all, I just want to kind of go over some things in the budget that struck my notice as I was going through, and maybe ask a couple of questions about them. Just help me, if you can, and explain some of the reasoning behind it. I am not trying to be critical, I just want to know.

Under Earth Sciences, I notice you have an actual increase over fiscal year 1990 from 13,730 to 18,450 under Instrumentation and Facilities. What new instrumentation and facilities are you going to be talking about to that level?

Dr. BERNTHAL. Mr. Perkins, I am again going to ask that Bob Corell—it happens that my senior science advisor heads the Earth Sciences Division. I will let them decide which one cares to comment on this.

Dr. CORELL. First, we thank you for your interest. The Instrumentation and Facilities part of the Earth Sciences has several full sides. One has to do with a development of a global seismic network.

Mr. PERKINS. I suspected as much.

Dr. CORELL. A digital network, to enable us both to look at earthquake and other phenomenon of that nature, as well as provide, if you will, a system around the globe to look at the internal structure of the earth. If you have enough of these around, you can do the equivalent of a cranial CAT-scan and look at the internal core of the earth, and use earthquakes as the sound source which then bounces off the various density changes in the earth's core, and give you, literally, a picture of the earth's core. So it is a very important fundamental part of our Earth Science program to expand in the same sense we are with the global change effort, to look at the globe in its totality.

Mr. PERKINS. There has been some projection in the past that the Chinese have had some really good advances in this area. Are you working in conjunction in any fashion with them?

Dr. CORELL. Yes. Also, we opened last Monday, or announced last Monday, a Science and Technology Center at the University of Southern California in cooperation with seven other institutions in that region to look specifically at earthquakes, a major earthquake research center, which has international connections as well.

Mr. PERKINS. Thank you very much. The second question I am interested in, I noticed under Astronomical Sciences your National Astronomy and Ionosphere Center gets a rather dramatic increase from actual 1990 to fiscal year 1991. I was wondering what was actually being done on that one, from about 6,219 to 11,270?

Dr. BERNTHAL. Yes. That refers to the Arecibo facility in which NASA cooperates as well. The chunk of money that is indicated there, and I believe it is in the order of $22 million, and Dr. Sanchez will correct me if I am wrong, is for the upgrade of that facility. It was approved recently by the Board. It is a specific project to improve the capability of the Arecibo facility.

Mr. PERKINS. Okay, thank you. And I notice in the Materials Research and Informal Science Education, there is a real emphasis on instructional materials development, of major proportions. I think that is good.

I wonder what set off this—you are talking about going from 21,170 to 31,000. That is a major, major increase. I just wonder what set off this big push.

Dr. BERNTHAL. In instructional materials?

Mr. PERKINS. Right.

Dr. BERNTHAL. By the way, I misspoke. Somebody reminded me it was 2.2 million, not 22 million.

Mr. PERKINS. I know, I understood. But that was for the actual amount proposed, but anyway.

Dr. BERNTHAL. Let me ask Dr. Williams to explain precisely what we are up to there. Because I think there are some exciting programs behind that number.

Dr. WILLIAMS. What we have done in the last several years is to try to make a transition from supporting, I would say a collage, of curriculum efforts that were not informed by them being comprehensively and broadly based and bore any relationship to the K-12 continuum. The large budget increase is to allow us to do the following: to have a coherent elementary level science curriculum that is linked to and informs a middle school math and science curriculum, appropriately integrated, followed by a high school math and science curriculum. So it was a substantial expansion for the program to simultaneously address it.

Mr. PERKINS. It seems like it is very much geared, looking at this, towards—I notice underneath you have towards improvements, for example Instrumentation and Laboratory Improvements gets a big one, undergraduate science engineers, mathematics. So it seems like materials, that sort of thing, is getting quite a bit of emphasis. I notice future preparation is not quite as targeted. I wonder if that, in conjunction with what you are doing, would perhaps be an item to look at.

Dr. WILLIAMS. Teacher enhancement, however, that is dealing with the teachers that are already in the work force, is the highest priority and it gets the largest increase.

Mr. PERKINS. Thank you. Lastly, getting over to the Antarctic Research, I am very pleased to see the increases that we have there.

I wonder, just in terms of—what is Operation Support? What does that mean? That's the one that keeps going up dramatically, and I just wondered what it was.

Dr. **Bernthal**. Let's see. The logistics part, per se, is $75 million.

Mr. **Perkins**. That stays constant.

Dr. **Bernthal**. That's right. That's for the Navy. The rest of it is our contracted activities for the general support of operations, I believe, but let me ask Bob again to elaborate on that.

Dr. **Corell**. As you may recall, in 1983, the President integrated under NSF full responsibility for all activities in the Antarctic. In other words, it was budgeted in one place, but to rely on the assets of the United States Government. The $75 million that is noted there is largely for those parts that are done with and through the Department of Defense.

Mr. **Perkins**. I noticed that.

Dr. **Corell**. But there are a number of other activities we must do in supporting our field parties. We have a contractor that provides vehicles, provides the support to the aircraft operations which are flown by Navy pilots, but the aircraft are in fact owned by NSF, the C-130s.

There is a whole network of facilities that support our science programs throughout the Antarctic. That is generally what we are talking about, operations. It is housing. It is feeding people. It is providing the vehicles to move them around. It is training them in the requirements to work, especially in a hostile environment.

Mr. **Perkins**. It just struck me that the actual increase in the research was going from $16.9 million to $19 million. That's barely $2 million, whereas you are talking about operations support going from $54 million to $81 million. That's a pretty dramatic increase in there compared to the actual increases in the research.

Dr. **Corell**. You will see that part of that increase has to do with two major developments. One, we are just in the final phases of putting online a research vessel with icebreaking capability that will be able to operate year- round in the Antarctic, and that is part of that. We are finishing up and will open in September a major new scientific research facility, a building with the best of scientific equipment that is not now possible to do, so field parties will be able to bring their samples, bring their instrumentation to the Antarctic and work in this facility. It will be open in November. So you see some of those.

Part of that also is the initiative I talked about earlier, the Safety, Environment and Health Initiative, which is designed to do those things we discussed a little while ago. So those are all in those operations budget. We try to work this out so it is clear this is science money that goes to the investigators who come from American universities, primarily, than the other parts of that, which is required to support their operations.

Mr. **Perkins**. I understand. I understand the necessity for the icebreaker. We have been talking about that for years.

Dr. **Corell**. It's finally going to be here. We will be able to go to sea on it.

Mr. **Perkins**. I just wonder, though, when you look at that, if you see the 54 to 71 and 17 to 19, there is a heck of a discrepancy. It just strikes the eye when you go through it.

Okay. I thank the Chairman.

Mr. Boucher. The Chair thanks the gentleman, whose time has expired, and now recognizes the gentleman from New York, Mr. Boehlert.

Mr. Boehlert. Thank you very much, Mr. Chairman.

This is my ninth year of my love affair with NSF and I am just so pleased to see the recommendation from OMB and the President, and the kind treatment that you receive in the budget. It is well deserved. I have jumped around in some areas. I have several questions I want to ask.

One, the National Center for Engineering Research is up for renewal this year. Do you have any projections of how much money and when?

Dr. Bernthal. Well, as I understand it, Congressman Boehlert, that process is underway right now. We are carrying out the five-year review and I am not quite certain what the target data for completion of that review will be. But John tells me it is May. We hope to have finished that evaluation by May of this year, and a decision will be made by the Board at that time or shortly thereafter then on continuing.

Mr. Boehlert. Any hints?

Dr. Bernthal. I will refrain from giving you any hints, but perhaps I can ask the officer in charge here to—

Mr. Boehlert. Are you upbeat, positive? That's what I want to know.

DMr. White. This is Dr. Ray Bowen, who is the Acting Assistant Director for Engineering, who will duck the question.

[Laughter.]

Mr. Boehlert. I can see Dr. Bowen is a very distinguished gentleman, and I welcome you.

Mr. Bowen. Since we are all claiming our geographical connections, I have spent a good many of my past few years at the University of Kentucky, but I see the Congressman has left, so I can't claim him. So I guess I have no choice but to try to answer your question.

The reports I get from the panel is that they are quite pleased with what they saw. That final report we have just received, and I think it would be inappropriate to provide too much more detail, but I think we see that center as making a valuable contribution to our earthquake program.

Mr. Boehlert. You are obviously a very astute, well informed, individual.

[Laughter.]

Mr. Boehlert. The next question is, everybody is talking about science education, how critically important it is. We had the Science and Math Excellence Act last year, and there were a couple of provisions in there. One was the Walgren Scholarships, the other was the Boehlert-Rockefeller Scholarships. Can you talk about them? Where we are going? And are we getting there in a hurry, I hope?

Dr. Bernthal. Well, there were two scholarship programs. I believe, if I understand the specifics that you are asking about here, one of which we are proceeding with, and the first of those was to work with the Department of Education to try and fashion a program that would be a kind of four-year merit scholarship, as I understand it.

Mr. BOEHLERT. Right. That's the Walgren program.

Dr. BERNTHAL. The President has requested $10 million for this initiative, and we are currently working with the Department of Education to try and fashion that program, looking forward to appropriations for that purpose in this fiscal year.

The other program, the so-called Robert Noyce scholarship, was one that was designed to be a two-year scholarship program.

Mr. BOEHLERT. To encourage young people, the best and the brightest, to consider education as a career path.

Dr. BERNTHAL. That's right.

Mr. BOEHLERT. You know and I know, and Congressman Gilchrest pointed it out, half the youngsters in American elementary schools are taking science courses from people not certified to teach science courses. How do we expect to be science literate as a Nation if the French teachers are teaching the kids science?

Dr. BERNTHAL. It's an issue that the Board has focused on. I think everyone understands that we have a serious credentialling problem and qualification problem for this critical precollege teaching area in science and math education. We are trying to address that problem in a far more systematic way, as I mentioned earlier, than before.

First of all, through that States Initiative program, then secondly, we hope to also through a similar, broadly structured program drive from the top down that will be carried out, we hope, within the universities themselves, the universities that are responsible, in large measure for training the teachers and credentialling those teachers.

Back to the specific, though, of the Robert Noyce scholarship program, which as you point out, would give a scholarship to students provided they are willing to make a commitment to teach when they graduate.

Mr. BOEHLERT. Two years for each year of the award.

Dr. BERNTHAL. That's right. We have not requested funding in the Foundation for this program because we still have not really been able to work out exactly how the follow-up, the policing effort, if you will, that would attach to that program, would be carried out. That is not the kind of effort that the Foundation easily engages in, as you can well understand. Moreover, the way the program was proposed to be funded, as I understand it, would require that NSF resources be transferred to the Department of Education.

So we have had some difficulties with the service and payback responsibilities and how you would follow up on those requirements within the Foundation, and therefore lacking a resolution of that issue, we have not requested funding for that program in this fiscal year. But we are certainly going to try and work with the new Secretary of Education, and I hope with this committee, to see whether we can come to some satisfactory resolution of those concerns.

Mr. BOEHLERT. That's discouraging and encouraging. It is encouraging that we have a new Secretary of Education. I recall that in the past we had some difficulty getting the Department of Education and National Science Foundation to work cooperatively on something that I think is critically important and transcends your dual missions. That is science education.

As a matter of fact, it took us about a year to get the former Secretary and Mr. Bloch here, and they met each other for the first time in this committee room. That's a sad commentary on the way we run things around this country.

But I'll tell you, we will give you the money. I think we are going to force it on you, because the concept is valid, and the cause is worthy, and I would encourage you, and everyone within NSF, to work diligently on this. Because we are going to force it on you, because it is needed. So pay some attention to that.

Now, the good news is we have a new Secretary of Education. I think you are going to find a greater degree of cooperation.

Dr. Good, would you like to comment on this, because I can see you are anxious to get in there.

Dr. **Good**. No, not really, Mr. Boehlert. This is a very difficult kind of a project for the NSF to do, because we do have to have the cooperation of the Department of Education. We would very much like to get a better working relationship with the Department of Education and the Board, in particular, has been somewhat frustrated through the years because of this problem.

If you look at the NSF's science and education budget, even with the increases we are requesting in 1992, it is still a small dollar volume, to do the problem that is sitting out there. Which means that the Foundation's major activity and major thrust is in catalytic kinds of things, rather than large programmatic kinds of things.

The Department of Education, on the other hand, is equipped to do those large, programmatic things. We need somehow to be able to get the catalytic kinds of things, and the innovative kinds of things that the Foundation is best equipped to do, to get those done at the Foundation and then to get them passed on, if you will, and get them institutionalized and built into programs across the country in the Department of Education.

That's the kind of environment we would like to see happen. We think that the NSF's ability to do the catalytic things, to do the experiments, to weed out of those experiments the things that work best, then to get the Department of Education to buy into those that work and institutionalize them, is the way to go.

Mr. **Boehlert**. Dr. Good, let me stress to you my feeling that NSF has not been the problem. It has been the Department of Education. Now we have some new players there, fortunately, long overdue.

Dr. **Good**. And I will tell you that we have no inherent reasons not to work with them. We will do our very best.

Mr. **Boehlert**. Well, attitude is everything. And I want you to have a very positive attitude.

Dr. **Good**. Absolutely.

Mr. **Boehlert**. Very good.

Dr. **Bernthal**. Mr. Boehlert, if I could just follow up for a moment?

Mr. **Boehlert**. Sure.

Dr. **Bernthal**. Clearly, the one thing we can do, and very easily, is also to work through the FCCSET structure, to try to get some resolution of that problem. I can also reassure you that this Secretary of Education is one that I know, and I have met, and won't meet for the first time at the table here. He is extraordinarily capable, as I am sure you know.

Mr. **Boehlert**. I share your enthusiasm for him, and the whole FCCSET process is good. Thank God we have Allen Bromley. We have got him. We are moving in the right direction. We have got the Administration's attention. They are very kind where they should be with this budget, particularly in their treatment of NSF. But I think it is critically important, that one, we acknowledge damn near total failure. Well, that's maybe overstating the case.

But in terms of science education in America today, there are a lot of shortcomings. We are trying to be part of the solution to the problem, and we have developed a program, and we want to see it carried out for all the right reasons.

One more, if I may indulge the Chairman. How do you conceive of the supercomputing centers fitting into the national High Performance Computing Program?

Dr. **Bernthal**. They will continue to be an essential feature in that program. They continue to receive strong support in this budget. They continue to work in developing some of the forefront software capability. But I am going to ask Dr. Brownstein, who has been intimately involved with that effort, the Acting Director for Computer and Information Sciences and Engineering, to respond in detail.

Mr. **Boehlert**. Dr. Brownstein, welcome.

Dr. **Brownstein**. Thank you. The NSF centers are, in the structure of centers across the country, leaders and providers of software and services for the other centers, including training. They will compete very well, I am sure, for the incremental resources in the national High Performance Computing Initiative. In fact, they have begun doing that.

Mr. **Boehlert**. We are still at five, aren't we?

Dr. **Brownstein**. We have four.

Mr. **Boehlert**. Four?

Dr. **Brownstein**. Cornell, Pittsburgh, San Diego, and Illinois.

Mr. **Boehlert**. Princeton has gone by the mark?

Dr. **Brownstein**. Yes.

Mr. **Boehlert**. Okay. I am glad you mentioned Cornell first. I don't mean to be parochial.

Dr. **Brownstein**. Cornell has actually done something very interesting, by picking up the SuperQuest program, which had been started by ETA, the company that went out of business, and was one of the reasons we are not still with Princeton. They instituted a national educational program, by which high school students come to Cornell, with IBM and NSF sponsorship, they and their teachers leave with five or six weeks of competitive instruction, let's say.

They all win. Everyone gets a workstation, they go back to their schools, they are then interconnected through the network. Their workstations go to those schools.

We intend, in fact Cornell was interested in vastly expanding that program as one of their special activities. But the other thing is that those centers are much bigger than —

Mr. **Boehlert**. Do you share that interest?

Dr. **Brownstein**. Do I share that interest?

Mr. **Boehlert**. Yes.

Dr. **Brownstein**. We support that interest.

Mr. **Boehlert**. I mean the vast expansion.

Dr. **Brownstein**. Absolutely. That's part of the initiative. About 15 percent of the money is called Basic Research on Human Resources. In that initiative, while you tend to focus on the technology, there is a substantial human resources part of that, so that not all the education and human resources is coming out of one place in NSF.

The centers are vitally interested in the education process. They all run summer institutes, for example, for high school teachers in their areas. We have created those things. We think it would be a mistake to earmark the money for this initiative.

We flatly know that they will compete extraordinarily well. They have all succeeded in getting some money, for example, from Dartmouth, and two of them from NIH, for their activities at their centers. So they are substantial enterprises that will do very well with the initiative, if supported.

Mr. **Boehlert**. It is a very exciting development, isn't it?

Dr. **Brownstein**. Yes.

Mr. **Boehlert**. I would like to thank you all very much, and Mr. Chairman, thank you and welcome to that chair.

Mr. **Boucher**. Thank you very much. The gentleman's time has expired, and the Chair now recognizes the gentleman from Florida, Mr. Bacchus.

Mr. **Bacchus**. Dr. Bernthal, I am Jim Bacchus from Florida. My district in Central Florida includes Kennedy Space Center, Florida Institute of Technology, the University of Central Florida and some excellent community colleges. Needless to say, we in Central Florida understand the importance of science education and of research and development as the key to our economic future. I strongly support the President's proposed increase for the National Science Foundation. I would like to see even more.

I do have a couple of questions. Your Academic Research Instrumentation initiative proposes $50 million to purchase state of the art research equipment. Now, spread among all the many colleges and universities in this country, that money won't go too far. Competition will undoubtedly be fierce.

Are there any prospects for increasing this amount in future years, and also, is there anything in your program to ensure that some of the smaller, lesser known institutions, which also have excellent research capabilities in this country, will be able to compete for these limited funds against the Harvards and Yales and Cornells of the world?

Dr. **Bernthal**. The short answer to the second question is yes, we certainly will take special note of the needs of smaller institutions, two-year colleges, four-year colleges, colleges without graduate programs will be eligible, to say the least, to compete for these funds.

We have not finalized, to say the least, a program announcement yet. We certainly would propose to take those factors into consideration. I would note that in the academic facilities program, indeed, we had a rather distributed effort, even though that amount of money was even less, trying to go to far more proposers and institutions than we may even get under the instrumentation program. The $50 million is certainly not insignificant, though.

The one point that I would make is that we are trying to address a rather specific price range of instrumentation through this program, a price range that has not been well covered by other programs. We have on the one hand multi-million dollar efforts such as telescopes and the LIGO effort.

On the other hand, for smaller instrumentation, let's say less than $100,000, such instrumentation is very often incorporated as part of the grant proposal from an individual investigator. We have structured this program so that in the range of $100,000 up to as high as $2 million, you would be eligible for funding provided 50 percent matching is available.

So the total cost of the equipment envisioned here is $200,000 up to as much as $4 million. Now, obviously not every institution, especially some of the smaller ones, will be able to meet that matching requirement. But I can assure you we will pay special attention, so that they have a shot at these funds as well as some of the more well-known major universities. That's by and large a general policy, in fact, of the Foundation.

I should also point out, as further response to your question, that we do have a very large instrumentation program that is on the order of $300 million overall. Some of that, of course, is for very large projects, but this is not the only shot, as I mentioned already, that the smaller schools and the individual investigators get in instruments. We are trying to cover a specific price range here, though, that had previously been very difficult to fit into our programs.

Mr. **Bacchus**. I applaud your effort, and I am happy to hear you are going to try to spread the money around. Obviously you agree with me, that the Ivy League has no monopoly on creativity in this country, and I say that as an Ivy League graduate.

I have an additional question. One of the major initiatives in your budget, it seems to me, is the establishment of High Performance Computing and Communications Network. This seems to me to be a necessary step toward keeping us on the cutting edge, as a country. I support that, as well.

I do have some questions about how you will implement this network. Do you have any plans for a regional or state model, possibly within some large state university system, and if so, what will be your criteria for selecting where to place this model system?

Dr. **Bernthal**. There is already a rather large variety of smaller networks which fit into our part of the larger NSF network, and will of course be part of the National Research and Educational Network envisioned under the High Performance Computing Initiative. If you are asking whether there would be a specific demo project to, for example, address some of the educational needs we discussed earlier—

Mr. **Bacchus**. That is my question.

Dr. **Bernthal**. Then let me turn to Dr. Brownstein, because he and Luther Williams both may have some thoughts on where we will be going with that.

Dr. **Brownstein**. Mr. Bacchus, the initial activity under this increment for the High Performance Computing and Communications Initiative is to sharply expand the number of institutions presently connected to the NSFNET. NSFNET reaches about 500 academic institutions, another several hundred commercial establishments, and through other networks, some 3,000 or 4,000 institutions that do research around the United States, alone.

There are within the NSFNET family, regional networks. NSF support the establishment of some of those regional networks and some of them, we have just got additional funds to upgrade equipment to be compatible with the rest of the network in the country. I believe Florida is served by two of the regional networks that NSF supports. In addition, there are a number of private companies beginning to develop which provide the initial stage of connectivity from institutions to the NSFNET backbone.

So it is a system with several tiers. There are some states that have their own regional network supported by the state, in particular North Carolina, Florida, and California has four state-supported by itself. I can't recall offhand whether Florida has its own, but our partnership in this whole activity is with state governments and private industry to develop the whole national system. I believe that every research institution in Florida is definitely on the network presently, and will be looking to expand services.

Mr. **Bacchus**. Again, let me say how much I support both of these initiatives. The two things that seem most critical to me in terms of developing our technology base in this country are one, access to communications and information, which that network provides; and two, access to the equipment and instrumentation that are increasingly necessary to solid scientific research.

One of the challenges we face is that by virtue of our past scientific successes, the capital costs attendant to producing future successes now have become prohibitive in many instances. To the extent we can help provide some assurance of access, not only to communications, but also to equipment and instrumentation, I think we are going to be able to take best advantage of all the creativity of our people throughout this country.

Thank you very much.

Dr. **Bernthal**. Mr. Bacchus, if I could just follow up for a moment?

Mr. **Bacchus**. Yes, sir.

Dr. **Bernthal**. I sense that one of the points you were driving at in your question was whether we have in place right now any plans or proposals for, shall we say, leading edge demonstrations. I think the short answer is that we are not quite there yet, because the first step would be to get this very high capability, not to mention a very high speed, network.

There are a variety of efforts underway in a number of universities to try to apply that technology in a general way. But I am sure that as the High Performance Computing Initiative proceeds that our Education Directorate will be working with the Computer and Information Sciences Directorate to try to develop the kind of thing you are mentioning.

I think right now, though, that is in the category of next step as we develop this capability.

Mr. **Bacchus**. This is an extraordinarily important program. I have been told that it could lead to remarkable advances, that it is in many ways akin historically to the decision to put the railroads on a single gauge more than a century ago. I applaud you for the effort and for the emphasis you place on it.

Thank you, Mr. Chairman.

Mr. **Boucher**. The Chair thanks the gentleman. The Chair has one additional area of focus for this hearing. And that is more of an institutional matter between the NSF and this subcommittee. In 1988, the Congress gave the NSF a five-year authorization that provided for better planning. I think we all agree that was an important step to take.

At the same time, the legislation that provided for that five-year authorization also required that the NSF submit to this committee, on an annual basis, a three-year estimate for the plans and projects that the Science Foundation has, with a projection of the amounts that would be expended in the major categories each year for the coming three years.

We have had less than an entirely satisfactory experience in terms of receiving those projections. Last year, in the report of the oversight of the National Science Foundation, this committee indicated, and I think in rather direct language, that it was less than entirely satisfied with the projections that had been made, and their reliability, and the extent to which they reflected the priorities that the NSF would have in coming years.

I will just quote a little bit from that language. It says "Unfortunately, the initial three-year budget submission for research and related activities contains no evidence of a prioritization process. The rates of funding increase for the individual scientific directorates are essentially identical. If not provided with meaningful three-year budget trends, the committee will be reluctant to endorse multi-year authorizations in the future."

Now, notwithstanding that rather pointed direction, unfortunately, we do not have a better experience this year. And your projects for even the next year in the major budget categories are again essentially identical. I could understand that, I think, with regard to fiscal year 1994, because obviously your projections that far out have to be, of necessity, a little more general. But for next year, for fiscal year 1993, I think we could expect to see some real prioritization of your numbers. We don't see that. And I would like to ask you why that is the case.

Dr. **Bernthal**. Well, first of all, Congressman Boucher, I would like to applaud the subcommittee for giving the National Science Foundation freedom throughout the five-year authorization process to be able to respond very quickly to new developments in science and technology. The other end of that bargain has been one that has been a little more difficult for us, and we are supposed to be on the delivery end of that, delivering it to the committee, and that is a projection that is reliable for three years out from the current budget date.

The only comment I would make there is that one of the key elements that has been driving our overall projections is of course the President's commitment to a doubling of the budget, which commitment I know the Congress has shared. So there has been a kind of baseline commitment that certainly underpins the uniformity of the numbers you have been getting.

Interestingly enough, I think if you examine at least the numbers for fiscal year 1992 that were provided in last year's projections with the actual numbers, they are in the aggregate for the directorates. Now, directorate by directorate, there is not all that much difference. There are specific programs within the directorates that have rather large variation.

But as I scan down through the directorates, there is not that great a variation, except in one or two cases, perhaps, that we can discuss. When a special emphasis develops, and it is in fact your five-year authorization that permits us to proceed apace with something like a High Performance Computing Initiative, Global Climate Change Initiative, which nobody foresaw prior to the summer of 1988, I guess it was, that's a very valuable freedom for the Foundation to have and I think it is in the best interests of the country and the Foundation.

Science within the broad categories of the directorates does not really change all that rapidly. So although the numbers we tend to send up here appear to be rather uniform and formula driven, I suspect that reflects our inability to see the special developments that always come our way on short notice of a year or sometimes even less that require an immediate infusion of funds.

So I understand the difficulty, I wish we could develop a better methodology for trying to foresee these special initiatives that we undertake, but so far we have not been able to do that.

Again, I would just point to the fact that within the broad budget categories, at least, we have not been all that far off the mark. The submittals are not terribly exciting, however, I will have to agree with you on that.

Mr. BOUCHER. Dr. Bernthal, I appreciate the answer. I am not going to put on my cross-examiner's hat here. I used to do that when I had a real job.

Let me just look at the evidence you cited and perhaps differ with it somewhat. You said that last year your estimates for fiscal year 1992 were not very different from what in fact came up in the budget recommendation. I would beg to differ a little bit with that. You are right, with respect to your first category, Biological, Behavioral and Social Sciences, you had predicted 12.1. The actual was 12.8.

In Computer and Information Science, however, you had predicted 11.8, and the actual was 23.3. With regard to Engineering, you had predicted 11.9, that wound up being 14.8. In Geosciences you had predicted 12, and the actual was 14. In Mathematics and Physical Sciences, you had predicted 12, the actual was 16.4.

In Scientific, Technical and International Affairs, you had predicted 12.2, the actual was 19.6. Then in the area of Education and Human Resources, and I am not seeing the exact corollary to that. It is listed as Science and Engineering Education. You had predicted 12.4, and the actual was 21.

I guess I would suggest to you that perhaps your experience, even for the past year, in terms of predicting what would be recommended this year, was not all that accurate. I am not scolding, I am just asking that you try to do a better job of this. Because I think we mean what we say, in that for us to do our work well, you have to be a little more help to us in providing projections of what your intentions are two and three years down the road.

Dr. **Bernthal**. We will do that as best we can. Now, without getting into a debate over the details here, one or two of the areas you mentioned, in fact did pop up rather late in the game on the screen. We did not know that the High Performance Computing Initiative, for example, was going to expand the budget to the 20 odd percent that it was within the computer science directorate. That was a decision made late in the process through the FCCSET process.

The Global Change budget, I think nobody would have predicted last year's increase, and I mean nobody, the overall Federal increased 56 percent, and again this year we have a large 22 or 24 percent increase through the FCCSET process.

So we don't have a good way of foreseeing what the actual accommodation to some of our requests will be in those areas. The Scientific Technological and International Affairs is a clear outlier here. That is driven primarily by two things. It is a relatively small amount of dollars compared to the others, and that is the formula driven Small Business initiative, and most notably the sizeable increase in EPSCoR.

So almost every year we have certain anomalies that creep in and render our efforts to project not terribly valid. But I take your point, and we will try and do better and do the best we can.

Mr. **Boucher**. Well, I appreciate that. The key point, of course, is that what we see in your projections for fiscal year 1993 and 1994 is essentially a flat landscape.

Dr. **Bernthal**. Yes.

Mr. **Boucher**. We don't get any information from this that satisfies the original reason that this requirement was put into the law. Perhaps if you could just provide us on an occasional basis with your projections of the new kinds of programs that you are going to have, any new initiatives that you see coming in the next couple of years, that would be another way to give us real information that might help us understand better what your plans and intentions are.

Well, I want to thank you very much for your attendance here this morning. It has been a very enlightening hearing. I want to thank you for your welcoming comments to me in this new position, and I very much look forward to working with you in the months and years to come.

Thank you very much. The hearing stands adjourned.

[Whereupon, at 12:15 p.m., the subcommittee was adjourned, to reconvene at the call of the Chair.]

FISCAL YEAR 1992 AND 1993 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

TUESDAY, MARCH 12, 1991

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE,
Washington, D.C.

The subcommittee met, pursuant to recess, at 9:30 a.m. in room 2318, Rayburn House Office Building, Hon. Rick Boucher [chairman of the subcommittee] presiding.

Mr. BOUCHER. This subcommittee will come to order.

Today we begin our second in a series of inquiries into the National Science Foundation's budget request for fiscal year 1992. Last week we examined a new initiative in high performance computing. We invite those who will be testifying today and tomorrow to comment generally on the balance and effectiveness of NSF programs, and specifically on new recommended initiatives in the area of advanced materials, research instrumentation, the LIGO project, and the absence in the Administration's budget of funding for research facilities construction.

Although the NSF share of all Federal research funding is approximately 10 percent, the significance of its programs to America's universities and colleges is critical. Foundation funding supports almost one quarter of all basic research at America's academic institutions, and of that one quarter, NSF sponsored research represents a very large portion of undirected research in the United States; that is, research whose primary purpose is to advance the frontiers of knowledge.

Most Federally-sponsored research is focused on the achievement of specific scientific goals, such as improved public health, energy independence, agricultural development, or national defense. But the National Science Foundation's mission is to protect the health of the national scientific enterprise and the research it supports is largely directed by the challenges that are inherent in science itself.

Many NSF programs provide the scientific foundation for subsequent mission-specific efforts at other agencies. Pioneering NSF-sponsored research into high temperature superconductors is only one example of that synergy. NSF plays a central role in maintaining the overall health of scientific and engineering research at our academic institutions. Through its educational activities the NSF helps our schools improve science and math instruction for all students and motivates future scientists and engineers.

To support NSF research and education activities, the Administration has requested a budget of $2.7 billion for fiscal year 1992. That represents an increase of 17.5 percent over the current year's appropriation level, and is consistent with the ongoing commitment to double the size of the National Science Foundation's budget by 1994, beginning with a baseline of fiscal year 1987.

During our first authorization hearing, we received testimony from the Acting Director of the National Science Foundation and from the Chairman of the National Science Board. During our hearings today and tomorrow, spokesmen for the academic community will present their views on the balance and effectiveness of the Foundation's priorities, as expressed in the fiscal year 1992 budget recommendation.

We have asked a very distinguished group of scientists and educators to assist us during these two days in that effort. The request includes $456 million for educational activities, and continues a trend of generally increasing support for education and human resource programs. More than one-half of that amount, $253 million, is dedicated to precollege initiatives, supporting a growing recognition that students in America's secondary schools generally lack the mathematical and scientific aptitude or even curiosity necessary to meet the technical challenges of the 21st century.

Our second panel today will advise us on the effectiveness of current programs and then comment on new directions that the NSF should take. In a moment, we will welcome our first panel of witnesses. Before doing that, though, I would like to call on the ranking member of this subcommittee, the gentleman from California, Mr. Packard.

[The prepared opening statement of Mr. Boucher follows:]

OPENING STATEMENT
OF
THE HONORABLE RICK BOUCHER (D-VA)
CHAIRMAN, SUBCOMMITTEE ON SCIENCE
ON
THE NATIONAL SCIENCE FOUNDATION AUTHORIZATION HEARING

March 12, 1991

Today we begin the second in our series of inquiries into the National Science Foundation's budget request for fiscal year 1992. Last week we examined a new initiative in high performance computing. We invite those who will testify today and tomorrow to comment generally on the balance and effectiveness of NSF programs and specifically on new recommended initiatives in advanced materials, research instrumentation, the LIGO project, and the absence in the Administration's budget of funding for research facilities construction.

Although NSF's share of all federal research funding is approximately ten percent, the significance of its programs to American universities and colleges is critical. Foundation funding supports almost one quarter of all basic research at America's academic institutions. And of that quarter, NSF-sponsored research represents a very large portion of undirected research in the US, that is, research whose primary purpose is to advance the frontiers of knowledge.

Most federally sponsored research is focused on the achievement of specific social goals, such as improved public health, energy independence, agricultural development, or national defense. But the National Science Foundation's mission is to protect the health of the national scientific enterprise, and the research it supports is directed largely by the challenges inherent in science, itself. Many NSF programs provide the scientific foundation for subsequent mission specific efforts at other agencies. Pioneering NSF-sponsored research into high temperature superconductors is only one example of this synergy.

NSF plays a central role in maintaining the overall health of scientific and engineering research at our academic institutions. Through its educational activities, NSF helps our schools improve science and math instruction for all students and motivates future scientists and engineers.

To support NSF research and education activities, the President has requested a budget of $2.7 billion. This is a 17.5 percent increase over last year's appropriation, and is consistent with the ongoing commitment to double the NSF budget by fiscal year 1994.

During our first authorization hearing, we heard from the Acting Director of the Foundation and the Chairman of the National Science Board. Today and tomorrow spokesmen for the academic community will present their views of the balance and effectiveness of the Foundation's priorities, as expressed in its FY 1992 budget request.

We have asked a distinguished group of scientists and educators to assist us in that effort.

The request includes $456 million for education activities, and continues a trend of generally increasing support for education and human resource programs. More than one half of that amount ($253 million) is dedicated to pre-college initiatives, supporting a growing recognition that students in America's secondary schools generally lack the mathematical and scientific aptitude or curiosity necessary to meet the technical challenges of the twenty-first century. Our second panel today will advise us on the effectiveness of current programs and comment on new directions the NSF should take.

Mr. PACKARD. Thank you, Mr. Chairman. I appreciate the chance to join with you in welcoming the witnesses today. We are grateful to have you here.

We do have a very distinguished panel of witnesses that will testify before us today, and I wish to thank you for scheduling the hearings and the hearings we have had in the past on this issue.

The President has proposed to increase NSF's commitment to education and human resource development to the $456 million that the Chairman has mentioned for Fiscal Year 1992. That represents a 23 percent increase over the previous year. The amount, $253 million, has been slated for precollege programs. That's a 19 percent increase in mathematics and educational efforts, and we are grateful for those increases. We hope that we can sustain them through the Congressional process.

As Dr. Bromley stated in his written testimony submitted to the Committee on Science, Space and Technology on February 20, 1991, "At the precollege level, mathematics and science achievements in the United States is a disgrace, with American students typically scoring at or near the bottom of international comparisons of industrialized countries." Of particular interest will be testimony on the systemic initiatives program, which is aimed at developing Federal-State cooperation in revamping education at the precollege level.

Again, Mr. Chairman, I want to welcome the witnesses, and I look forward to hearing their testimony and appreciate their attendance here today.

Mr. BOUCHER. The gentleman from Indiana, Mr. Roemer.

Mr. ROEMER. Thank you, Mr. Chairman. I do not have a formal statement, but I would like to make a couple of comments in welcoming the distinguished panel and I also enjoyed my conversation with Dr. Green prior to her testimony on the second panel. I look forward to seeing and hearing her comments.

One of the things I would like to have the distinguished panel look at and comment on in their testimony would be the facilities of modernization program. In my district at the University of Notre Dame a new building is going up on campus that will have a fiber optic cable going into it, and if they could comment on how common this is, and how we can get support for facilities modernization throughout the country, not just in my district, but get these fiber optic cables that Senator Gore testified about earlier last week, and the importance of those to our young children as well. Dr. Green and I were talking about that.

Secondly, I am delighted to see attached to your testimony, Dr. Langenberg, the "Science: the End of the Frontier?". My brother is a researcher down in Louisiana and has been telling me for the last year how difficult it is for young researchers and scientists to get grants and funding. The future is so bleak for these young people, let alone, as Dr. Green and I were saying, that we need to inspire our young people in the elementary and middle school level into higher education and to teaching, and to the teacher institutes eventually throughout the country. I look forward very much to hearing your testimony today.

Lastly, I would just like to say that I think the kids in our grade schools and middle schools are ready and able and willing and eager to learn in the science and mathematical areas. I got some of my best questions on the technology in the Persian Gulf issue from fourth and fifth grade students. They were as anxious to get back and work on their Nintendo games—they are computer literate in many ways. We need to tap into that talent. I am very eager to hear the testimony today.

Thank you.

Mr. BOUCHER. The Chair thanks the gentleman. The gentleman from Arkansas, Mr. Thornton.

Mr. THORNTON. Thank you, Mr. Chairman. Let me join in welcoming our distinguished panel of people who know better than most people in America the vital importance of scientific research, the morale problems which are caused by inadequate support for that research. We are very much looking forward to your testimony today.

In particular, I also want to say how pleased I am to have the opportunity of again being in the room with Dr. Langenberg. While I was Chairman of the Committee on Science and Education, of the AAAS, we had some opportunities to work together. Your predecessor at the University of Maryland was so generous in giving us about a two or three day session on how to accomplish strategic planning for the University of Arkansas system. I want to thank you for his great leadership there and hope your strategic plan is moving forward. We have to do our best to use our scarce resources in a wise way. I think we also need to do some strategic planning for the scientific enterprise in America.

Thank you, Mr. Chairman.

Mr. BOUCHER. The Chair thanks the gentleman. The gentlewoman from Michigan, Ms. Collins.

Ms. COLLINS. Thank you, Mr. Chairman. I am very pleased to be at this hearing, Dr. Langenberg, and I am very interested in what will be given to us today.

I worked at Wayne State University in the Physics Department for approximately 10 years. I was a business manager, but I know the significance of the NSF grants. We could not have had a Physics Department nor the significant research programs we had without the National Science Foundation. I am looking forward to your testimony.

Thank you, Mr. Chairman.

Mr. BOUCHER. The Chair thanks the gentlewoman.

We will now be pleased to welcome our first panel of witnesses. Without objection, their opening statements will be made a part of the record. We will ask that they provided about a five-minute summary of their statements.

Our first witness will be Dr. Donald Langenberg, Chairman of the Board of the American Association for the Advancement of Science and Chancellor of the University of Maryland College System.

We also welcome—and I am personally pleased to extend a welcome to one of my constituents—Dr. Gary Hooper, the Vice-Provost for Research and the Dean of the Graduate School at Virginia Tech in Blacksburg, Virginia. We welcome Dr. Robert Gavin, the President of Macalester College in St. Paul, Minnesota. We will be pleased to hear from the witnesses in that order, so Dr. Langenberg, we will begin with you.

STATEMENT OF DR. DONALD N. LANGENBERG, CHAIRMAN OF THE BOARD, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE; CHANCELLOR, UNIVERSITY OF MARYLAND SYSTEM

Dr. LANGENBERG. Thank you, Mr. Chairman. Let me thank you and your colleagues for providing this opportunity to testify at this important hearing on the NSF authorization for fiscal year 1992.

As you noted, I am currently Chancellor of the University of Maryland System. But I am here before you today in my capacity as Chairman of the Board of the American Association for the Advancement of Science. You have my written statement explaining that organization, so I would like simply to make a few major points.

First of all, as has been noted in recent months, Dr. Leon Lederman, who is my successor as President of the AAAS, undertook an informal survey of morale in the academic and scientific community. There is a copy of his report to the Board appended to my statement. The responses were, I am afraid, a little dismaying. It was an opinion survey, in effect, but the opinions and perceptions that were expressed indicated that there is a rather deep malaise in the academic and scientific community.

A good many accomplished researchers are being demoralized by the difficulties in obtaining research funding. The frustrations they experience and the diminished expectations, particularly among the younger researchers, span all the disciplines of the research community. It has been indicated that the future of some leading research programs and teams is in doubt.

This is rather ironic, because by many indicators, the American science enterprise is strong and healthy. It can perhaps be argued that it has never been stronger and healthier. There is a strong perception among policy makers and the public that that is so. Where comes the problem, then? It is true that over the past decade, Federal funding for basic research has fared relatively well. Nevertheless, overall funding in real terms for academic research is larger but not much larger than it was in 1968, more than 20 years ago.

But there are nearly twice as many researchers competing for those funds as there were 20 years ago. Furthermore, modern research is dealing with the tough problems. The easy ones having been dealt with in the past. The cost of acquiring knowledge, the cost of the rather complex and sophisticated instrumentation that is required has increased considerably. There have also been significant increases in regulatory requirements and that, too, has added to the indirect costs, but without providing direct benefits to the conduct of research.

Dr. Lederman's conclusions have been borne out by other surveys recently, one by the American Physical Society of young academic physicists, another of the biomedical community, a Gallup poll sponsored by the Pharmacological Manufacturers' Foundation. The NSF budget that you have before you from the Administration would increase NSF's budget substantially. Under the President's plan, overall budget authority for non-defense R&D would go up by 9.5 percent in fiscal year 1992. Within that, as you have noticed, there is a plan to augment the NSF budget by more than 17 percent, to a total of $2.7 billion.

As you know, over the past several years, the Administration has proposed doubling the NSF budget over a period of five to seven years. But actual appropriations have fallen short of that goal. The proposal for this year's budget would put NSF back on the doubling track, based on fiscal year 1987 as the base year.

There are a set of highlights in my written testimony, which I will not go through, but let me simply comment in response to your suggestion, that there is increased strength across the board. There are some concerns on the part of some disciplines, some broad disciplinary areas about the magnitude of the increases. There is a proposal for a very substantial increase in the Directorate for Education and Hhuman Resources. That is very gratifying.

So, too, is the proposal for a $50 million initiative, a Presidential initiative, for academic research instrumentation. That would address directly the problem of how to acquire the sophisticated instrumentation really required to do state of the art research.

There is a source of concern in the fact that the budget proposal includes a proposal to terminate the Congressionally-initiated Research Facilities Modernization Program. This is the only existing competitive matching grant program among the Federal agencies which is aimed at the modernization of academic research facilities, and has been seen in the community as a pilot, as a harbinger of increased Federal interest in the question of how we provide up-to-date physical facilities for our researchers.

As you know, this is a massive problem. It is not one that the Federal Government could ever hope by itself to solve. It is one that our institutions, our academic institutions and their sponsors, our States, private donors, must play a major role in. Nevertheless, it is a significant problem as we consider the potential future productivity, and perhaps even viability, of our academic scientific enterprise. The absence of a Federally-funded competitive grants program to assist in solving the facilities problem is a matter of substantial concern.

Overall, AAAS strongly supports the Administration's proposal. We are pleased that the NSF budget has been given particularly high priority in a constrained budgetary situation. The Administration's commitment to NSF is particularly gratifying, given the gap on domestic discretionary spending that is provided for in the recent Budget Enforcement Act.

Full funding of the NSF budget request, even of all the R&D programs, would not fully address the problems that are being faced by the research community, the problems that were highlighted by Dr. Lederman's report. Nevertheless, they would be a large step in the right direction. The NSF funding strategy is clearly such a step. It will help to improve the funding situation for individual investigators. Equally important, it will contribute to the development of human resources through improved science and engineering education at all levels, and through enhanced minority participation in science.

The AAAS hopes that the Congress will see fit to fully fund the NSF request and perhaps even to augment it in appropriate areas, though we realize this will be very difficult given the constraints.

Finally, the AAAS very much appreciates this committee's long-standing concern about the state of American academic science, and its strong interest, particularly, in science education at all levels. Your continued support of this NSF budget will show that the United States is indeed committed to strengthening its scientific infrastructure. The Association is eager to help you in any way it can, and I will be happy to answer any questions you may have during the course of this session.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Langenberg follows:]

Statement by

DONALD N. LANGENBERG

Chairman

American Association for the Advancement of Science

Before the

Subcommittee on Science

Committee on Science, Space, and Technology

U.S. House of Representatives

March 12, 1991

INTRODUCTION

Mr. Chairman and Members of the Subcommittee:

Thank you for giving me the opportunity to testify at this important hearing on the National Science Foundation (NSF) Authorization for 1992.

I am Donald Langenberg, Chancellor of the University of Maryland System. I appear before you today in my capacity as Chairman of the Board of Directors of the American Association for the Advancement of Science (AAAS).

The AAAS is a membership organization of 133,000 scientists and engineers, and has 295 affiliates representing more than five million members in various scientific, engineering and other professional societies. AAAS publishes the journal, Science, as well as policy reports addressing a variety of issues facing science and its related professions.

Among the Association's most long-standing areas of policy studies is its annual series of analyses of federal funding for research and development. For the past 16 years, AAAS, with the aid of its affiliated scientific, engineering and higher education associations has been monitoring R&D in the budget. The Association publishes a report on the President's budget each spring, holds a colloquium in Washington in April, and prepares a wrap-up report on Congressional action on R&D in the budget each fall. As a result, AAAS has a well-informed historical view of trends in federal funding commitments for R&D and the contributions that research can make to the nation's economy, security, and quality of life.

In addition, several months ago, Dr. Leon Lederman (who was at the time President Elect of AAAS and who has now succeeded me as President) undertook an informal survey of morale in the academic scientific community. His report -- a copy of which I am submitting for the record -- has stimulated wide discussion of the science funding situation. The responses from nearly 250 academic researchers on which the report is based indicate that even the most accomplished researchers are being demoralized by the difficulties of obtaining research funding. Profound frustration and diminished expectations span across all disciplines of the research structure, and the future of many promising research programs and teams is in doubt. Ironically, this situation exists in spite of the perception among policymakers and the public that American science is strong and healthy.

Over the past decade, federal funding for basic research has fared relatively well in budget battles -- at least in comparison to other federal program areas. But, as Dr. Lederman's report points out, despite recent growth, the level of federal support for basic and applied research in the universities, after correcting for inflation, is not much larger today than it was in 1968 -- more than 20 years ago. Compounding the problem is the fact that there are twice as many doctoral scientists in universities competing for those funds. Moreover, in all areas of research, the "easiest" problems have been solved, and the cost of acquiring knowledge about the remaining more complex scientific problems has increased considerably. Finally, new regulatory requirements have added to the overhead costs and reduced the funds available for the direct costs of research.

These factors help explain why, despite continued increases in the federal budgets for research for the past several years, academic scientists are still suffering from a funding squeeze. Dr. Lederman's survey suggested that the funding situation is having a variety of deleterious effects on academic science. It is leading research to stick with "safer," more fundable areas of research. It is discouraging graduate students and under-graduates from pursuing scientific careers. And it is diminishing the ability of faculty to serve as proper role models for their graduate students.

In the face of this situation, support for NSF, a keystone of academic science, is crucial.

THE NSF BUDGET IN PERSPECTIVE

The Administration's proposed budget for FY 1992 gives R&D high priority. According to AAAS figures, under the President's plan, budget authority for nondefense R&D would increase by 9.5 percent to $31.1 billion in FY 1992. Defense R&D is slated for an even larger increase: up 12 percent to $44.5 billion. Overall, the funding level for R&D in FY 1992 would be more than $75 billion, 11 percent above the $68 billion appropriated this year.

Large increases are proposed in the R&D programs of several agencies, including DOD, NASA, and NIH. Among the proposed increases is the plan to augment the NSF budget by more than 17 percent, from $2.3 billion to $2.7 billion. As you know, each year for the past several years, the Administration has proposed doubling the NSF budget over a period of five to seven years, but appropriations have fallen short of this goal. This year's budget would put NSF back on the doubling track, using FY 1987 as the base year.

Strong funding for NSF is essential to the health of academic science in the United States. Numerous government and privately-sponsored reports and studies support the strong connection between investment in science, engineering and education and our technological and economic development, as well as national welfare and future security. In one widely-cited recent paper, economist Edwin Mansfield of the University of Pennsylvania studied the rate of return on investments in academic research. His work covered 76 major firms in seven industries. Even with conservative assumptions, his results are impressive: the annual social rate of return on investments in academic research is no less than 28 percent.

Since NSF funds account for roughly 15 percent of all federal funds for R&D in colleges and universities, and 25 percent of federally-funded basic research in these institutions, the availability of NSF support is a crucial component in determining the welfare of the academic science enterprise. A number of reports have indicated that success rates for individual investigator-initiated proposals to NSF in several fields have declined markedly in recent years. The Administration's FY 1992 budget proposal for NSF is responsive to the need to assure that the success rate of NSF proposals will increase to a level consistent with a healthy and vigorous scientific community.

HIGHLIGHTS OF THE NSF BUDGET

The FY 1992 budget proposes the following major changes and initiatives:

- Funds are requested to strengthen the research base and infrastructure, including a $269 million increase for Research and Related Activities -- a 15.9 percent boost over the FY 1991 current plan for a total of $1.96 billion.

- In Biological, Behavioral and Social Sciences, all but three programs will achieve at least a small margin of real growth; eleven programs will increase by more than 10 percent over their levels five years ago (in constant dollars).

- In Engineering, six programs will remain below their 1988 levels (in constant dollars); three will grow by less than five percent; the rest will attain greater growth.

- Seven programs in the Directorate for Mathematics and Physical Sciences will remain below their 1988 levels; seven others will grow five percent or less above their pre-FY 1988 levels.

- If significant cuts are made in the FY 1992 request, however, many -- perhaps most -- programs in Math and Physical Sciences will again fall below their FY

1988 levels in real terms. At full funding, real increases above FY 1988 levels will be small; mathematics up 5.7 percent; astronomy up 6.0 percent; physics up 2.3 percent; chemistry up 1.2 percent and materials research up 4.8 percent.

- Extending efforts of the past several years, the budget requests additional funds to develop human resources, broaden participation and improve science and engineering education and training at the precollege, undergraduate, graduate, and postgraduate levels. The total for Education and Human Resources would be $390 million, $67.6 million more than the current plan for FY 1991, an increase of 21 percent.

- One program of special note is a $50 million Presidential Initiative for Academic Research Instrumentation. This is a new, competitive program for high-cost, state-of-the-art instruments with a cost-sharing requirement of at least 50 percent.

- At the same time, however, the budget proposes to terminate the congressionally-initiated Research Facilities Modernization Program, the only existing competitive matching grant program for the modernization of academic research facilities among research agencies.

CONCLUSIONS:

NSF IN BROADER BUDGETARY CONTEXT

We are pleased that the NSF budget has been given high priority in this restrictive budget climate. The Administration's commitment to support of NSF is that much more significant given the cap on domestic discretionary spending contained in the Budget Enforcement Act.

As you know, the Budget Enforcement Act (BEA) of 1990 divides discretionary programs into three groups, with separate caps for defense, nondefense and international affairs. For FY 1992, the BEA allows the nondefense category to keep pace with inflation, rising about four percent above 1991 levels. Within the cap, the budget process sets up a "zero-sum" game. In other words, greater than four percent for one program will require decreases in other programs. Despite the limits, as I noted earlier, the President has proposed to increase nondefense R&D by 9.5 percent (to $31.1 billion) while maintaining an overall increase in discretionary nondefense spending of four percent. This is clearly in recognition of the importance that R&D plays in our strength as a nation. The strong budget for NSF is one of a number of increases for research-intensive agencies.

Full funding of the NSF budget request -- even of all the R&D requests -- will not fully address the problems faced by the research community. According to some reports, intensifying competition for limited funds is leading NSF to make a larger number of smaller grants and to hold awards to an average duration of two years, not the three years proposed a few years ago as a means of bringing more stability to the research enterprise. Moreover, the erosion of the value of research awards in constant dollars is requiring researchers to expend excessive resources hustling for research dollars from multiple sources to support the work of a single laboratory. Researchers report that the constant search for funding is a major distraction from their research.

Whatever the outcome of this year's budget battle, the problems documented by the Lederman survey are likely to continue for the foreseeable future. Nevertheless, the NSF funding strategy is a step in the right direction. It will help to improve the funding situation for individual investigators. In addition, it will contribute to the development of human resources through improved science and engineering education at all levels and through enhanced minority participation in science. AAAS hopes the Congress will see fit to fully fund the NSF request, and perhaps even find ways of increasing it. We realize this will be difficult given the constraints.

AAAS appreciates this Committee's longstanding concern about the state of U.S. academic science, as well as its interest in science education at all levels. Your continued support of the NSF budget at this vital juncture will show that the U.S. is indeed committed to strengthening its scientific infrastructure. The Association is eager to assist in any way it can and will be happy to answer any questions raised by this Subcommittee or provide you with additional information.

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Donald N. Langenberg was educated at Iowa State University (B.S.), the University of California, Los Angeles (M.S.), and the University of California, Berkeley (Ph.D.). All his earned degrees are in physics. He also holds honorary degrees (M.A. and D.Sc.) from the University of Pennsylvania.

After a postdoctoral year at Oxford university, Dr. Langenberg joined the faculty of the University of Pennsylvania in 1960, as Assistant Professor of Physics. He held the rank of Professor of Physics from 1967 to 1983, and had a secondary appointment as Professor of Electrical Engineering and Science from 1976 to 1983. While at Penn, he served as Director of the Laboratory for Research on the Structure of Matter (an interdisciplinary materials research laboratory) and as Vice Provost for Graduate Studies and Research.

In July 1980, President Jimmy Carter appointed Dr. Langenberg Deputy Director of the National Science Foundation. He served in that position through December 1982, and served also as Acting Director of the Foundation during the first six months of his tenure.

In 1983, Dr. Langenberg became Chancellor of the University of Illinois at Chicago (UIC), where he also held the rank of Professor of Physics.

On July 1, 1990, Dr. Langenberg became Chancellor of the University of Maryland System. The System comprises eleven campuses and four research and service components.

Dr. Langenberg's research was in experimental condensed matter physics and materials science. His earliest research was concerned with the electronic properties and Fermi surfaces of metals and degenerate semiconductors. A major part of his research career was devoted to the study of superconductivity, particularly the Josephson effects and nonequilibrium superconductivity. He is perhaps best known for his work on the determination of certain fundamental physical constants using the ac Josephson effect. A practical consequence of this work was the development of a radically new type of voltage standard which is now in use around the world. One of the major publications resulting from this work is among the most frequently cited papers published by the Reviews of Modern Physics during the 1955-86 period, and has been dubbed a "citation classic". The work has also been recognized by the award to Dr. Langenberg and his co-workers of the John Price Wetherill Medal of the Franklin Institute.

Dr. Langenberg is the author or co-author of over one hundred papers and articles, and has

Dr. Langenberg has held predoctoral and postdoctoral fellowships from the National Science Foundation, the Alfred P. Sloan Foundation, and the John Simon Guggenheim Foundation. He has been a visiting professor or researcher at Oxford University, the Ecole Normale Superieure, the California Institute of Technology, and the Technische Universitat Munchen. In addition to the Wetherill Medal, he has been awarded the Distinguished Contribution to Research Administration Award of the Society of Research Administrators, the Distinguished Achievement Citation of the Iowa State University Alumni Association, and the Significant Sig Award for the Sigma Chi Fraternity.

Dr. Langenberg has served as advisor or consultant to a variety of universities, industrial firms, and governmental agencies. He serves or has served on numerous boards and commissions. These currently include the Board of Directors of the American Association for the Advancement of Science, of which he is Chairman; the Board of Directors of the Alfred P. Sloan Foundation; the Board of Trustees of the University of Pennsylvania; the Board of Governors for Argonne Laboratory; and the Executive Committee of the National Association of State Universities and Land-Grant Colleges, of which he is Chairman.

Dr. Langenberg was born March 17, 1932, in Devils Lake, North Dakota. Since 1953 he has been married to the former Patricia Warrington, who is currently Associate Professor of Epidemiology and Biometry at UIC. They have four children: Karen, a marketing executive; Julia, a veterinarian; John, a physician; and Amy, at the moment a journalist. Dr. Langenberg's avocational interests include photography, history, and travel; he has visited or resided on all seven continents.

3/11/91

Mr. **BOUCHER.** Thank you, Dr. Langenberg. We will withhold questions until we have heard from all our witnesses.

Dr. Hooper, we will be happy to hear from you next.

STATEMENT OF DR. GARY R. HOOPER, VICE PROVOST FOR RESEARCH AND DEAN OF THE GRADUATE SCHOOL, VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY; ACCOMPANIED BY ERNEST STOUT, ASSOCIATE PROVOST FOR RESEARCH

Dr. **HOOPER.** Thank you, Mr. Chairman and committee members. We are most pleased to be here before you. I am Gary Hooper, Vice Provost for Research and Dean of the Graduate School at Virginia Polytechnic Institute and State University. I will say that only once to save my time.

We do represent, I believe, the type of university that is most appreciative and interested in the National Science Foundation. We are an institution of 23,000 students, about 4,000 of which are graduate students. We are the largest institution in Virginia, and have a strong research program of about $120 million in annual expenditures. I believe the views we will try to bring before you represent other like institutions and like faculty around the country.

In presenting this viewpoint, we have grouped things into four categories that seemed of most interest and concern to us. One is the need to maintain and strengthen the University-Government, and particularly National Science Foundation, relationship that we have had for some time. Another is the need to continually identify and support emerging technologies and concepts.

The third is the need to deal with some matters that are of global concern and international scientific and concern. Finally, the need to encourage education in the sciences and develop the next generation of professionals. These are not in priority order.

I have a couple of comments on the University-National Science Foundation research relationship. We are also very supportive of the proposed budget for the National Science Foundation. We find it appropriate and balanced. We are interested in a couple of particular aspects concerning the facilities. We, too, have noted that the research facilities have been removed from this budget, that support.

I just want to point out that as near as we can tell, there is no group in the country willing to step forward and take the leadership in developing facilities. Modernization is a problem. The faculty of today goes into buildings that were built in World War II and slightly after. Nothing in those facilities will maintain and support the kind of instrumentation and research they wish to do.

So leadership on the part of the National Science Foundation in restoring this program would be most welcome, and would perhaps signal to others the need to continue in support.

We were very encouraged that the new Academic Research Instrumentation Program is included in this budget. Again, those instruments have a very short life. In several years, they may be obsolete. We are continually upgrading or replacing this instrumentation, and it, too, is vital to the continuation of this research partnership we have.

Let me speak a moment about some of what we have considered emerging technologies and concepts. We have particularly noted the great support given for material synthesis and processing in this budget. We are a university with particular strengths in that area, and wish to go on record thanking the National Science Foundation for its continued support of a center that we have in high performance polymeric adhesives and composites. We feel this is a good continuation of that sort of work.

We encourage the National Science Foundation to continue to evaluate emerging technologies and to have as their priorities the support of certain of these.

A third item, the global and international research, would include some comment on these large national facilities that are contained within the budget. We are concerned at this time that we continue to maintain and signal our interest in leadership in the international community in science and research. We have seen the emergence of a more unified European science enterprise and continued growth of Japanese and other technologies. We believe we need to be competitive and work with these organizations. Some of the facilities proposed would serve both our national interests and these international concerns.

One thing we might add here is the thought that as we develop the costs of these large facilities, it seems important to us to understand the full cost of putting these facilities on line and maintaining them. We would hope that future budgets would keep that in mind, with the National Science Foundation.

The final item, education and science and development of future professionals, would be our highest priority if we had assessed priorities. We are concerned with indications that a sizeable number of all young people are avoiding some of the sciences. Particularly minorities and women seem to be indifferent to opportunities to careers in the sciences. As the population shifts in these areas, we feel it is very important that we keep that in mind. The program Alliances for Minority Participation, a $10 million item in the budget, is again a most welcome indication of leadership on the part of the National Science Foundation.

We would encourage a massive investment in all science and engineering graduate fellowships, continuation of what is in the budget, or even increases so that we can continue to entice the highest quality graduate students into these areas, rather than see them leave to lower level positions because of the competition of the job opportunities that are there.

Again, we appreciate this opportunity to go on record as being very supportive and appreciative of the National Science Foundation's proposed program and budget. We believe that this added emphasis on educational programs is particularly noteworthy.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Hooper follows:]

Testimony before the Science Subcommittee of the House Committee on Science, Technology and Space

Subcommittee Chair - The Honorable Frederick Boucher,
Committee Chair - The Honorable George E. Brown, Jr.

by Gary R. Hooper,
Vice Provost for Research and Dean of the Graduate School,
Virginia Polytechnic Institute and State University

March 12, 1991

I am pleased to have the opportunity to come before you this morning to offer comment upon the concerns and opportunities before us in our university/government relationship.

I am joined by Dr. Ernest Stout, Associate Provost for Research in representing our institution and our research community in these comments. I believe they represent views of similar research universities across the country.

Virginia Tech is the largest university in Virginia and is the primary land grant institution of the state. We are an institution of 19,000 undergraduate students, 4,100 graduate students, 1,800 faculty and a strong support staff. With over $120,000,000 in sponsored research expenditures in the past year Virginia Tech is 48th on the NSF ranking for total research expenditures. Our strength in the sciences, engineering, mathematics and other disciplines supported by the NSF gives us a good perspective for our comments.

In this testimony we have identified these issues of greatest significance to our research community and have related our concerns to the most recent NSF program and budget document.

Our comments can be grouped under four main categories; they are not in priority order.

- The need to maintain and strengthen the University/ Government (NSF) partnership.
- The need to identify and support emerging concepts and technologies.
- The need to support global research concerns and international scientific interactions.
- The need to encourage education in the sciences and development of the next generation of professionals.

University/Government Research Partnership

The U.S research university is a unique blend of traditional academic scholarship and research which supports our intellectual and economic standing amongst the nations of the world. Federal support of university research has been a feature of this country since World War II, and has contributed to the development of most of the scientists now practicing in this country. Recent years have seen NSF encouragement of University/Government/Industry partnerships that have particularly served our national competitiveness.

We wish to call attention to this unique aspect of the U.S. educational system, and urge continuation of strong funding for the NSF.

One concern for the future of this relationship is exemplified by the absence of any appropriation in the 1992 FY NSF budget, (0 dollars vs $ 39,759,000 in FY 1991) for Research Facilities Modernization.

Research Facilities have truly become "nobody's baby." State governments have been unable to keep pace with our needs; industry sponsors will rarely fund facilities; and, the federal government is increasingly reluctant to participate. That an overwhelming backlog of facilities construction and modernization exists is amply documented by several studies (see the summary in "Perspectives on Financing Academic Research Facilities: A Resource for Policy Formulation" - published by the Government/University/Industry Research Round Table).

The facilities problem is both quantitative and qualitative. Most institutions simply don't have sufficient floor space to accommodate the needs of their research programs. More importantly, however, much of academic research space is not suitable for today's technologically sophisticated research. At our University, and at most others, much of the available space was built before World War II. That space is seriously outmoded for today's research needs. Even those facilities constructed in the post-Sputnik era of the late fifties and early to mid-sixties now require major renovations to meet the needs of modern research and to satisfy health and safety requirements, handicap access, etc.

If our progress in science and technology research is to continue at the pace required to maintain this country's leadership, major investment in research facilities and infrastructure is required. There is a need for new facilities and a need for renovations of existing facilities. Various studies have estimated the dollar cost to address the problem. These estimates vary, but all agree it is a multi-billion dollar problem.

I would urge the subcommittee to give serious consideration to continuing the Academic Research Facilities Modernization Program. I believe the funding should be increased from the 1990-1991 authorization of about $20M per year to $100M per year by 1995.

While the federal government has not been the primary source for funding research facilities, the NSF exclusion of this category seems particularly poorly timed and of concern during this time of economic stress in many states. If we are going to be urged to avoid special appropriations from Congress for facilities, we need to have a competitive source for such critical funding.

The lack of facilities to match the sophistication of our science and scientists may prove to be a major stumbling block to progress.

On the positive side, the increase in overall funds for the NSF is most encouraging to us. For example, we applaud and enthusiastically support the proposed new Academic Research Instrumentation Program ($50M). The rapid development of new instrumentation is required to keep pace with the development of new methodologies and technologies. In fact, the two are synergistically entwined. Developments in one drive developments in the other. Most academic institutions simply cannot keep pace from their own resources with the need to replace instrumentation that becomes obsolete, in many cases, in three to five years . We urge this new initiative be funded at the proposed level.

Support of Emerging Technologies and Concepts

Virginia Tech is particularly appreciative of increased funding in materials synthesis and processing. ($84 million)

We have long felt that materials research was of critical importance to the nation, and have established a variety of interdisciplinary research and instructional programs. Our NSF Science and Technology Center in "High Performance Polymeric Adhesives and Composites" is in its third year of operation, has been a catalyst for increased private funding, and attracts exceptional students and faculty. NSF's added investment in university research will bring great dividends to the nation by stimulating industry investment and developing a cadre of capable professionals.

The initiation ($213 million) of an inter-agency initiative (via the Federal Coordinating Council on Science, Engineering and Technology) is likewise applauded. The need for continual development in computing and networking concepts - and the resulting national system - will serve all institutions well. The academic community thrives upon rapid exchange of data and results. That critical synergy between institutions, large and small, also depends upon the systems to come forth from this effort.

We encourage the NSF to continue to evaluate emerging technologies and to support those which have potential for significant impact upon our national priorities in science, technology and education.

Global and International Research Including Large National Facilities

At least two of the FY 1992 proposed NSF priorities (U.S. Global Change Research - $118 million; U.S. Antarctic Research - $22 million) represent investment in issues of significance to the global community. U.S. (and NSF) leadership in such research signals our intent to maintain our standing as world leader in such issues, and will validate the expressed interest of our scientists in working with their counterparts in other countries.

We are especially concerned that we find common ground for competitive research programs at this time of emergence of a more unified European science, and continual growth of Japanese science and technology. We must remain competitive in science and involved in the international community to maintain our technological position.

Clearly, the construction of large national research facilities are beyond the capability of any single institution or consortium of institutions. Therefore, the Federal government must be the funding source for such needed new facilities as the Laser Interferometer Gravitational Wave Observatory (LIGO) and the new Optical/Infrared Telescopes. Forward progress in many fields of science is dependent upon the availability of such facilities.

However, I would offer two [redacted] and concerns. First, these large facilities are not just national in scope, but international. They will assuredly benefit very directly science and technology development in all developed countries, and many undeveloped ones as well. That being the case, an international funding mechanism seems justified and appropriate. The economies of Japan, Western Europe, Korea, and many others are robust and capable of cooperating in a meaningful way in the funding of international research facilities. Second, I am concerned about the out-year costs of operating and maintaining large national research facilities. Over the useful life of such a facility, the initial costs of construction may be a minor fraction of the total. I would urge that such facilities be fully costed over the anticipated useful life, so that informed decisions can be made initially. If a significant fraction of the annual NSF budget is consumed with operating and maintaining large national facilities, then I do have a concern.

Education in Science and Development of Future Professionals

This area is our highest priority for continued NSF support. We are acutely aware of the general decline in interest and even capability in science and mathematics of prospective undergraduate and graduate students. We are equally concerned with indications that a sizeable portion of minorities and women seem indifferent to opportunities in a career in the sciences. As the nation's population mix shifts towards Hispanic and African American youth, we are concerned that these groups are being excluded from the sciences for a variety of reasons. In addition, the prospects of even replenishing the current scientists, teachers, and professors in these areas seems almost beyond our reach.

At Virginia Tech we find ourselves increasingly in competition with other colleges and universities for prospective graduate students. We believe the NSF is very much on track with its proposal to allocate $582 million for education and human resource development.

The focus upon early involvement of students and revitalized undergraduate curricula is welcomed. The "Alliances for Minority Participation Programs" ($10 M FY1992) is of interest, as are special funds to address the needs of women, minorities, and people with disabilities. We would also encourage a massive investment in all science and engineering graduate fellowships so that we can continue to attract the highest quality students before the enticement of high-paying, entry-level positions dilutes the pool of potential future professionals.

We appreciate this opportunity to go on record as very supportive of the NSF proposed program and budget, as well as the opportunity to suggest additions and modifications to that program.

It is our impression that the added emphasis upon educational programs and minority/gender programs provides a good complement to the traditional research funding. The programs, with the exception noted earlier about facilities funding, are appropriate, although our faculty in social sciences feel there should be added emphasis in their areas.

The question of future budgets might be our primary concern. The creation and maintenance of special facilities and interdisciplinary centers, while very worthwhile, creates an added burden of baseline funding that drives the annual budget up or squeezes other programs out.

Mr. **Boucher**. Thank you, Dr. Hooper. Dr. Gavin, we will be pleased to hear from you.

STATEMENT OF DR. ROBERT M. GAVIN, JR., PRESIDENT, MACALESTER COLLEGE, ST. PAUL, MINNESOTA

Dr. **Gavin**. Thank you Mr. Chairman, and other members of the committee.

I would like to express my appreciation, first to the committee, for the efforts you are taking in this area to become fully informed on what I think is probably the most important issue facing the country today. That is education in research and science. There is no question in my mind as President of a small college how important it is for us, but I think too, our Nation badly needs to move ahead and to have a consensus on what the key issues are that we are dealing with in this area.

We are particularly fortunate now to have a growing consensus. The President, the science advisor, the leadership in the National Science Foundation, and, I think the spirit of the appropriation and the discussion here, is very much moving in one direction, that is to support education at all levels.

What I have highlighted in the testimony that I submitted is a plea for balance in these areas, to recognize that it is extremely important, when we are talking about education to recognize the role of precollegiate, collegiate education and graduate education. In addition, the balance and the interaction between education and research is absolutely crucial for us. Finally, to remember that big science and small science are an important part of maintaining the progress for this country.

Today I am going to have my remarks directed to the undergraduate level, but I would like to say from the very beginning that I fully support the new efforts in precollegiate education and the continuing efforts for the support of graduate education and research activities. All areas need to be supported.

For undergraduate institutions, it is particularly important that we have an opportunity to speak about the close interaction between teaching and research. Briefly, my background is as a Ph.D. in physical chemistry from Iowa State University, undergraduate of St. John's University in Minnesota, where I majored in chemistry and mathematics.

The institutions where I have been since my graduation have mainly been undergraduate liberal arts colleges. I spent 18 years at Haverford College in Pennsylvania, seven years now at Macalester College, and throughout my entire career I have been committed to the point of view that research and scholarship in teaching are of one cloth.

Research and education are easily divided when one comes to categories you might have on an organizational chart. But we know, I think, at undergraduate institutions, that what works there in terms of producing good scientists and people in the biomedical profession is an education which is laboratory-rich, hands-on, which involves the students from the very first years in the experimentation and the method which is crucial to science. So when we talk about research and education, we are talking about one topic.

Course and curriculum development are extremely important. I am delighted to see the emphasis in the appropriation, and would in fact urge greater emphasis in this area. At a place like Macalester and the other institutions I am speaking for today, research activity on the part of the faculty is closely connected to curriculum development. In addition, it is closely connected to all the activities in the instrumentation area.

We fully support the initiatives in the instrumentation area. We believe that it should be expanded even more. Institutions such as undergraduate liberal arts colleges have been in a situation over the last several years where the amount available for institutions of our type has pretty much leveled off. We at Macalester have been very successful in competing for these funds, and it has had a tremendous impact on education from the first-year introductory courses right through the senior courses. The instrumentation is driven by scholarly interests of the faculty, their involvement in cutting edge science, and the involvement of the students from the very first years in that activity.

We are also delighted to see the integration between research and teaching, that alphabet soup of programs that may not mean much to you, but it certainly does to us. It is important to us, RUI, ROA, UFE, REU, etc., that the National Science Foundation has. Those programs tie the research activity to the teaching activity. We think that is an extremely important concept, and one which if one looks at the types of background of our scientists today, you find a very strong correlation between the scientists' involvement in research activities at the undergraduate level, and then their going on to further degrees, Ph.D.s., M.D.s., in the biomedical profession or in pure science. There is a very strong correlation between undergraduate research activity and completion of programs.

We also think it is extremely important that there continues to be an emphasis of having these research activities on liberal arts college campuses. We feel that good science is science which is done in a social atmosphere where we create an atmosphere of involvement and interaction between persons.

We all know the tremendous success that big science projects have had in terms of creating a community of learners, those interactions that are so important for the moving ahead of these projects. Exactly the same thing applies at the undergraduate level. In fact, we believe there is strong evidence to indicate that the more that community of learner's atmosphere is promoted at the undergraduate level, the more successful we are in keeping people in science and moving them on.

We also believe that the new efforts in terms of partnership and communication are extremely important. Macalester is, like most undergraduate liberal arts colleges, about 1,800 students. We happen to be very fortunate to be located in a metropolitan area, very close to a large research university, the University of Minnesota. However, many other colleges are located in small towns, and don't have immediate access. Through technology today, we believe we can overcome some of those shortcomings.

My final point is with respect to research facilities modernization. We think this is a crucial area. The facilities on most campuses have not been renovated for a number of years. If you think back at how science was carried out and what the important facilities were 20, 30 or 40 years ago, it is a completely different environment.

So we want first to thank you for having this program in existence and initiating that effort, and also urge you to include it in this appropriation. We fully support the competitive nature and we welcome the opportunity to compete.

Thank you very much.

[The prepared statement of Dr. Gavin follows:]

TESTIMONY

Robert M. Gavin, Jr.
President, Macalester College
St. Paul, Minnesota

THE NATIONAL SCIENCE FOUNDATION

FY 1992 BUDGET REQUEST

March 12, 1991

UNITED STATES HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON SCIENCE

Speaking for
The Associated Colleges of the Midwest
The Great Lakes Colleges Association
The Central Pennsylvania Consortium
Reed College, Allegheny College

INTRODUCTION. I am very pleased to be invited to participate today in this oversight hearing on the National Science Foundation Fiscal Year 1992 Budget held before the House Subcommittee on Science, Research and Technology. For Macalester College; for our peer institutions within the Associated Colleges of the Midwest, the Great Lakes Colleges Association, and the Central Pennsylvania Consortium; and for Reed College, Allegheny College and the other institutions served by The Independent Colleges Office, the National Science Foundation (NSF) is a significant partner in our efforts to build and sustain strong programs in science and mathematics. We recognize and appreciate the critical role this Subcommittee plays in ensuring that the partnership between NSF and predominantly undergraduate institutions is most productive.

Two perspectives inform my comments. First, I am a chemist and have spent almost my entire academic career at liberal arts institutions. I received my undergraduate degree from St. John's University in Minnesota. I was a faculty member and provost at Haverford College for eighteen years until coming to Macalester College as president seven years ago. When I speak about science and mathematics in the liberal arts setting, I speak from experience in classroom and lab. If my words sound passionate, it is because I am deeply committed to the kind of teaching and learning that takes place on such campuses.

Second, I speak as a college president well aware of the need to establish institutional priorities for strengthening science and mathematics programs within the context of broader national goals for the year 2000. I recognize the hard choices that must be made--by colleges, by federal agencies, and by Congress--if faculty, curriculum, instrumentation, and facilities are to be sufficient for the task. I also realize the need to be accountable both for the establishment of priorities and for the use of designated funds.

Today in this Oversight Hearing on the NSF FY 1992 Budget Request I would like to emphasize the importance of balance:

1) in the distribution of support;
2) between research and education programs; and
3) between "big science" and "little science"

within the total NSF agenda.

Fiscal Year 1992 is a critical year for undergraduate programs within NSF, as well as in the other federal agencies that provide support for science and mathematics in the nation's schools, colleges, and universities. This is the first year that the NSF budget process has been shaped by discussions within the FCCSET Committee on Education and Human Resources. This is the first year that Dr. Luther Williams, as NSF Assistant Director for Education and Human Resources, has the responsibility (and opportunity) to work with his NSF colleagues in setting priorities and developing budgets for undergraduate programs. This is the first year under the leadership of Dr. Walter Massey, as new Director of the National Science Foundation. This conjunction of "firsts" means that people will be watching very carefully the signals that are sent by the NSF Budget, and by the response of the Authorizing and Appropriating Committees of the House and Senate to this budget.

Those "firsts" are a significant part of the context for this Oversight Hearing. The process for determining NSF policies and budgets takes place in the context of a national consensus about the nature of the challenges facing America. The alarmingly low level of scientific and technological literacy in the general population and the severe under-representation of minorities and women in science and mathematics fields have been well-documented, as has the need to ensure a steady supply of well-trained professionals for careers in science and technology into the next century. Perhaps the most significant aspect of the context for these discussions is that there now seems to be a national consensus, from the President on down, about what needs to be done to strengthen science and mathematics programs at all stages in the educational continuum. We are ready to stop analyzing; we are ready to make needed reforms.

Needs of the nation's elementary and secondary schools have been receiving much deserved attention in recent years. Also, the nation's academic research enterprise is receiving considerable attention. My purpose today is to emphasize that undergraduate education also makes a crucial contribution to addressing national needs in the area of science and mathematics, and must continue to be supported in relation to that contribution. It is heartening to note that the FCCSET report, as well as statements made by Dr. Williams, Dr. Massey, by Dr. D. Allan Bromley, Science Advisor to President Bush, and by your own Chairman, Congressman George Brown, gives increased attention to the undergraduate academic experience.

The undergraduate years provide critical opportunities for strengthening our nation's science and mathematics capacity. It is here that future scientists and college faculty are recruited and prepared for graduate study, that our nation's elementary and secondary teachers, educators of America's youth, are equipped and renewed, and where students who will be leaders of tomorrow gain the capacity to make critical decisions in a world permeated by vital issues of science and technology.

Unfortunately, at the undergraduate level, many able young people decide to discontinue their study of science and mathematics. The result is an irreparable loss of talent to the service of the nation, a loss that we cannot afford if we are to remain competitive in a global economy.

Undergraduate education in science and mathematics takes place in many settings, both independent and public: liberal arts colleges, doctoral institutions, and two-year institutions. Each sector of the educational community plays a distinctive role in the total national effort to educate a competitive workforce and a scientifically literate populace. Liberal arts institutions, such as the ones for which I am speaking today, have no monopoly on programs that work in undergraduate science and mathematics. Institutions of all kinds have achieved success.

There are certain principles, however, that guide strong programs in science and mathematics in the nation's liberal arts colleges, such as Macalester. On our campuses faculty are as committed to undergraduate teaching as to their own intellectual activity; faculty see students as partners and engage them in learning that is experiential, investigative, and hands-on. Learning takes place in a community in which students gain confidence that they can succeed. These principles can provide direction to inform the process of setting priorities and budgets within NSF and within other federal agencies. My colleague, President Melvin D. George from St. Olaf College, addressed such issues in his testimony to you last year. I commend his remarks to you.

POINT #1: BALANCE IN THE DISTRIBUTION OF NSF SUPPORT.

If the educational goals set by President Bush for the Year 2000 are to be met, NSF support must be directed toward and available in a balanced and equitable way to each sector of the educational continuum--precollege, undergraduate, and graduate levels. To achieve the balance and equity required, we must extend and expand existing NSF programs. We also must include persons with experience and expertise from each of the educational sectors at the table as decisions about priorities and budgets are developed, implemented, and assessed. Achieving balance and equity will require a visible, highly-coordinated effort within NSF for all undergraduate activities.

The strength of American education derives from its diversity. The one overriding feature of the whole enterprise is that what characterizes the strength of American education--its diversity--also generates the biggest challenge to improving it. In no other country in the world is the population that is to be educated, and the circumstances in which that education is carried out, as diverse as in the United States.

Not only are students ethnically, culturally and racially diverse, but they come from diverse economic, social, geographical and demographic backgrounds, many of which are intertwined with each other, and from education systems and practices with different origins and histories. This diversity, which is also reflected in the identity and mission of the nation's colleges and universities, makes it imperative that we examine carefully the balance and equity in support available through the NSF to the diverse sectors of the academic and research communities.

Several studies have consistently reported very strong productivity rates in the natural sciences by independent predominantly undergraduate colleges. Especially productive are the 140 private colleges in the Carnegie "Liberal Arts I" category. These colleges are second only to the category of Private Research Universities in the percentage of Ph.D.'s in science and mathematics awarded to their graduates. This productivity is for both men and women.

Even more significant is the production of science and mathematics baccalaureates by the undergraduate colleges. Again, as a percentage of bachelors degrees awarded, independent liberal arts colleges (Carnegie Classification I) rank first overall and first in the production of women science and mathematics graduates. These colleges, with 3% of the undergraduate enrollment, award approximately 10% of the nation's total baccalaureate degrees in the natural science and mathematics. This same group of colleges received, in FY 1988, 1% of the total NSF obligations for science and engineering. It is not uncommon to find liberal arts colleges graduating more majors in basic sciences and mathematics than nearby universities that are ten times as large. Among the smaller institutions that produce relatively large numbers of science graduates are women's colleges, and the Historically Black Colleges and Universities. This is significant, given that the student groups they serve are traditionally under-represented in science and mathematics.

I do not intend to make the point that we do better with less money, or that the major research institutions, be they public or private, would do better with less. We recognize the critical role major universities have in ensuring that the nation's research base is firm and can continue to make an essential contribution to address the challenges facing this nation. My purpose in providing this testimony is to make the point that scarce dollars must be distributed in a more equitable manner to address national needs. I describe below how increased support would be used by the institutions for whom I speak.

That members of this Subcommittee recognize the need for such balance has been demonstrated in your persistent support for predominantly undergraduate institutions, particularly through the College Science Instrumentation Program. Equally important was your insistence that the recent NSF program for research facilities modernization be directed toward needs in all sectors of the educational community. I urge your continued vigilance in this regard.

POINT #2: AN APPROPRIATE BALANCE BETWEEN RESEARCH AND EDUCATION.

Within the NSF budget, balance and equity between support for education and support for basic research is crucial if national needs in science and mathematics are to be met. The international challenges to America's competitiveness in science and technology are apparent to everyone. It is equally obvious that basic research is essential for the continued competitiveness and leadership of this nation. However, attention to basic scientific research without comparable attention to the educational programs that produce and renew scientists is like building a castle on sand. All the money in the world to carry out basic research will not help this country unless we have the scientific personnel capable of making the best use of that money.

The current system, on campuses or within federal agencies, has not achieved an appropriate balance between teaching and research. Placing blame for past decisions is not productive. Our charge is to work together to change the system.

Dr. Walter Massey, the newly-confirmed Director of the National Science Foundation, testified last week before the Subcommittee on VA, HUD, and Independent Agencies, House Committee on Appropriations. In his testimony he spoke directly to the commitment of NSF in this regard:

> ...Finding solutions to [the challenges facing our nation] will require continuing investments in science, technology, and human resources. NSF is committed to helping to find these solutions by strengthening the research base and infrastructure and improving science education and opportunities for all students. (Underlining added.)
>
> ...NSF is helping to strengthen the natural linkages that exist between research and education. These two activities are not distinct, but together form the basis for developing and applying science and technology to society's needs.

In considering an appropriate balance between research and education, it is instructive to examine founding documents of the NSF. We find abundant evidence that Vannevar Bush, who laid out the original plan for an entity such as the NSF, plainly saw the interconnections between research and education and the necessity for supporting both, recognizing that tomorrow's researchers are today's students, and thus must be well taught:

> Publicly and privately supported colleges and universities...are charged with the responsibility of conserving the knowledge accumulated by the past, imparting that knowledge to students, and contributing new knowledge of all kinds.
>
> It is my judgment that the national interest in scientific research and scientific education can best be promoted by the creation of a National Research Foundation...[which] should develop and promote a national policy for scientific research and scientific education...[and] should develop scientific talent in American youth...

The Budget Justification for the NSF FY 1992 request reiterates this earlier vision of Vannevar Bush:

> To succeed as a nation in a time of change requires a large and continuing effort to educate our citizens and to create and apply new ideas. Highly educated scientists and engineers and a technically competent workforce are essential for the nation's future. In the international arena the comparative advantage is now determined by access to sophisticated knowledge and the ability to use it effectively. The NSF plays a vital role in generating and disseminating this new knowledge and creating a technically competent workforce.

Despite this rhetoric, I believe that the budget as requested falls short of achieving a healthy balance between education and research.

Testimony, Page 5
President Robert M. Gavin, Macalester College
March 12, 1991

In my opinion, and in that of a great many persons actively engaged in undergraduate science, four crucial activities should receive immediate priority at NSF:

- reform of introductory science and mathematics courses for undergraduates;
- continued and expanded support for the integrated teacher-scholar role at undergraduate institutions;
- reform of teacher preparation and teacher enhancement programs; and
- expanded support for partnerships among and between all academic sectors.

Let me explain by describing efforts in the two priority areas mentioned above--course and curriculum development, and faculty enhancement:

Introductory courses: The recently published FCCSET report describes the situation extremely well:

> In addition...many experts believe that undergraduate science, mathematics and engineering education has suffered from a lack of attention, which has left it stagnant, diminished its quality, and led to a dull and uninspiring student experience. As a result, there is increasing concern about the quality of the academic experience itself, particularly during the first two years of the four-year undergraduate sequence.
>
> In a number of critical fields, undergraduate courses are virtually the same today as they were 20 years ago. As a result, curricula are often narrowly focused, despite the fact that some of the most exciting research growth areas today are not within scientific disciplines but between them. Undergraduate course work needs to keep pace with changes in scientific research, both for science majors and non majors. [p. 40]

There is no argument that reform of introductory courses must have the highest priority. The need to reform introductory courses is clearly articulated in documents from disciplinary associations such as the Sigma Xi and the AAAS. The response from the academic community to NSF's expansion of the Course and Curriculum program in 1991 is one indication that institutions are ready to move ahead aggressively in restructuring introductory courses. As you know, this was the first year that all science and mathematics disciplines were eligible to compete for awards in this program, moving from a focus on calculus and engineering in previous years. With $8 million budgeted, the NSF received over 720 proposals requesting over $90 million for first year support. The multi-year requests covered in these proposals asked for over $250 million. It is clear that the need is there; it is equally clear that the academic community has significant plans for course and curriculum reform, and are eager to present these plans for peer review.

What is needed is a major commitment by the NSF to enter into partnerships with the nation's colleges and universities to make essential reforms in introductory courses at the undergraduate level. This proposal pressure indicates great unmet demand; funding levels are not adequate, less than half that recommended for this activity by 1992 in the 1986 Report of the National Science Board on Undergraduate Education (the Neal Report). It will take more than the $18 million requested in the FY 1992 NSF request to reform introductory courses with all deliberate speed. It will take, at a minimum, double that amount.

I propose consideration that the Course and Curriculum Development Effort be funded at double the current request, bringing it closer both to the $43 million recommended by the Neal Report, and to the level of interest demonstrated by response to the first competition of the expanded program. These increases would parallel the requested $50 million for the Presidential Initiative for Research Instrumentation.

Instructional instrumentation: Support for adequate instrumentation is another critical factor in reforming undergraduate introductory courses and curriculum. The NSF College Science Instrumentation Program (CSIP) was re-instituted (by Congressional action) in 1985, after the devastating de-emphasis of undergraduate science and mathematics at NSF in the early '80's. Exhibit I presents the history of the CSIP/ILI effort at NSF since that time. You will note that CSIP funding has been static at about $16 million in 1990, 1991, and 1992.

This exhibit should be reviewed in the context of the NSF FY 1992 request for $392 million in research instrumentation, which includes $50 million for the Presidential initiative for Research Instrumentation and $40 million for LIGO. This request is a 32% increase in support for research instrumentation in the upcoming fiscal year.

Although they represent substantial increases, the combined recommendations for undergraduate instrumentation (both ILI and CSIP) and for course and curriculum development in the NSF FY 1992 Request fall short of the Neal recommendations. They also fall short of the amount needed if we are to adequately address the top FCCSET priority for undergraduate programs: to support curriculum and materials development and laboratory improvement. If the recommended funding levels in the Neal Report for undergraduate laboratory instrumentation had been achieved, they would have been at $39 million in 1991.

I propose consideration by this Subcommittee, as well as by the House and Senate Appropriation Committees, an increase of 32% in the CSIP/ILI program, which would bring this activity to a funding level of $30.3 million, rather than the level funding that has been the circumstance for the past three years.

My colleagues and I will be persistent in making the case that what some have called "white-collar" science (a passive, lectures-only, hands-off approach) does not work at the introductory level--or, indeed, at the upper levels. Adequate, state-of-the art instrumentation is essential for students at all stages in their undergraduate careers. Students need to be actively engaged in asking their own questions, in discovering their own answers through hands-on activity in laboratories. Again, proposal pressure gives us one indication that the academic community is ready to move ahead quickly if resources are available to do so. Again, our concern for balance in support of undergraduate programs requires that we remain persistent in this regard.

Faculty: Now I would like to turn to the second priority area for strengthening undergraduate science and mathematics: expanded support for the integrated teacher-scholar role at undergraduate institutions.

Each of the NSF programs that provide support for faculty should be described and implemented from the perspective of the learning experience for students, not solely from the perspective of faculty development. The NSF Revised Notice #107 issued last August signals this intent when it directed that "Each proposal for renewed support of a research project must include, as part of the required summary of results of the completed work, information describing its contribution to the development of human resources in science and engineering...."

At the NSF-funded Project Kaleidoscope National Colloquium held at the National Academy of Sciences in early February, one of the themes was that hands-on, discovery-based, laboratory-rich teaching works. It is this approach to teaching in science and mathematics that produces significant numbers of science and mathematics students. This approach requires the appropriate instrumentation described above; it also requires that the teaching faculty be active as scholars, involving students as partners in their research.

NSF helps make these desiderata possible through its Undergraduate Faculty Enhancement (UFE) Program, and through its support of research at predominantly undergraduate institutions with the Research in Undergraduate Institutions (RUI) and Research Opportunity Awards (ROA), and Research Opportunities for Undergraduates (REU) programs. These are all valuable programs; it is critical that they be continued. It is equally critical that the administration and implementation of these programs be monitored to ensure they serve the community most effectively. I urge your continued support of these excellent initiatives.

The existing programs for Research in Undergraduate Institutions (RUI), Research Opportunity Awards (ROA), and Undergraduate Faculty Enhancement (UFE) are good, but insufficient. For example, as important as it is, the RUI program supports only the top layer of the most aggressive of our faculty. In 1988, out of some 70,000 science, mathematics, and engineering faculty in predominantly undergraduate institutions, only 172 received a RUI award--1 out of 400! NSF made 70 Research Opportunity Awards (ROA) in 1988, about 1 in every 1000 of the four-year college science and mathematics faculty.

As now implemented, the UFE program focuses primarily on new disciplinary advances, rather than on connecting such advances to enhancing the undergraduate academic experience. At current levels of funding, the UFE program can touch only about 1% of undergraduate faculty per year. The Neal Report recommended NSF spending of $17 million in this area by 1991 (using a modest 5% annual inflationary increase); the FY 1991 request for $6 million, though increased over last year, is still inadequate. In addition, no program exists that supports faculty leaves of absence to pursue a combination of disciplinary research, enhancement of teaching, and course development. Such a program would be extremely valuable for faculty at our institutions.

Faculty development programs at NSF must be expanded to include opportunities to pursue scholarship on the home campus, as well as in conjunction with research teams at other institutions. Support also must be available for faculty to explore and implement curricula that are new in both form and content, incorporating new technology, pedagogical approaches, and disciplinary advances. This increased support should be in addition to current support for the research opportunities for undergraduate faculty described above. The importance of such programs cannot be overlooked as we seek to broaden the opportunities for undergraduate faculty.

Faculty development and enhancement is one of the FCCSET priorities for undergraduate activities. To accomplish this, reward structures (within institutions and within NSF--where rewards equal grants) need to be changed to recognize the integrated role of the teacher-scholar. Good teaching needs to be defined, rigorously sought out, and promoted. That is the case at the colleges I represent, but it should also be part of the structure of the NSF budget. It is a key factor in our success in attracting and sustaining student interest in science and mathematics; the allocation of funds in the NSF budget should reflect this commitment.

The recently passed "Excellence in Mathematics, Science and Engineering Education Act of 1990" is one solid step in this direction, declaring that grants are to be awarded based on the impact such awards would have on the undergraduate experience of students. However, I caution members of this committee, as well as the NSF staff, in developing plans to implement this new program, to be sensitive to the differing needs of the different sectors of the educational community. The colleges for which I speak have long emphasized teaching and close contact between student and faculty. We would be penalized for past and present successes if only those programs proposing major structural changes on campuses were competitive.

I urge your consideration of a wider range of programs through which undergraduate science and mathematics faculty can keep abreast of disciplinary advances. The interactive combination of teaching and scholarship that takes places on many of the campuses for which I am speaking results in the most effective and engaging education for undergraduate students. Students learn best from faculty who know what is happening in their fields and in related fields and how to incorporate that knowledge into classroom and laboratory experiences for their students.

Students. Equally valuable would be a third, parallel track for the current REU to enable more home-based opportunities for faculty and students to engage jointly in research. The opportunity to work with faculty in research has been shown repeatedly to be the critical pump in keeping students involved in science and mathematics. In addition, it is perhaps the very best way for undergraduate faculty to build and reinforce their role as teacher-scholar.

The REU program should receive four to five times the level of support it currently receives, perhaps determined in some ratio to levels of support for graduate fellowships and traineeships. Additional support for research experiences for undergraduates--working as research apprentices to science and mathematics faculty--would be more productive in attracting and sustaining student interest in science and mathematics over both the short- and long-term than the undergraduate fellowship program currently under development.

The current program benefits about 1% of undergraduate faculty and students, providing good opportunities, in most cases, for students to move for the summer months into major academic or government research labs. To be successful in the current REU competition requires that the host investigator have a project (or series of projects) that will accommodate ten students. This, and the requirement that half of the students be from off-campus, does not serve the need to have students and faculty engaged jointly, linking classroom and laboratory during the academic years as well as during the summer. The previous Undergraduate Research Participation Program did a better job in this regard.

POINT #3. BALANCE AND EQUITY BETWEEN "BIG" AND "LITTLE" SCIENCE.

In advocating the interconnection of teaching and research means that, like Vannevar Bush, my colleagues and I advocate research done in academic settings. This kind of research has traditionally been what is called small science. Over the years since The Endless Frontier was written, science has grown larger, more sophisticated and more expensive. (I wonder whether he could have foreseen the enormous level and scale of the class of projects that today we call big science.)

Whether one talks about research or education, we must preserve diversity in our scientific endeavors. We should avoid becoming a mono-culture in every sense of the word. The benefit that comes from funding a diversity of promising projects should not be sacrificed by deciding to fund only big science projects. Both big science and small science have their role in the national structure.

It would be comforting to be able to say that all research and education projects, big and small, are good and leave it at that. But in today's world that would be naive. Whether we like it or not, big science has a major impact on small science.

Nothing I say here today will turn attention away from big science. But, particularly in this Oversight Hearing on NSF, it is important to take note of essential characteristics of small science and of the benefit of such projects to the entire scientific enterprise. Small science projects are more apt to be scrutinized at every stage by peers, as they are conceived, designed, described, reviewed, conducted, assessed, and published. Small science helps more in producing the next generation of scientists; this becomes particularly critical as we seek to attract more women and minorities into science.

As James Powell, President of Reed College, said in a recent address:

> Without adequate support for Small Science, the research infrastructure in our colleges and universities will decay even further, perhaps beyond the point of repair. It is in the setting of small science--the colleges and universities--that tomorrow's citizens take their last science course, the one on which their ability to participate as intelligent voters depends. Most important of all, funding for Small Science represents the life-giving water that the seed corn--the next generation of researchers--must have if it is to live and to flourish. Thus, I submit: support of Small Science is not optional; it is a requirement vital to every interest of our nation, even to the ability of our democracy to function.
>
> The key is to ensure that an overview takes place so that an appropriate balance is struck and the interest of Small Science is protected.
>
> One way of accomplishing this would be to have funding for Small Science indexed, however roughly, to spending for Big Science. I believe that Congress or the Office of Science and Technology Policy could develop such an idea. For every increase in spending on Big Science, a proportionate increase would occur in the budgets of NSF and NIH.
>
> Another useful step would be to require each Big Science project to have a plan showing how it would help to improve the state of the human and physical resources of the nation's science base. As Frank Press has said, the highest priority has to be people. Next, we have to maintain and improve the infrastructure of teaching and research. Big Science projects can and should be required to make a significant contribution to these needs.

If one uses a measure of +$100 million to define Big Science, few education projects fall into this category. Certain activities--current and proposed at NSF--could reach such levels, in areas my colleagues and I support. These are activities relating to two of the undergraduate priorities I outlined at the beginning of this testimony--the reform of teacher preparation and teacher enhancement, and the development of partnerships among and between all academic sectors.

Precollege activities. My analysis of the NSF budget for precollege activities indicates that adequate support is requested for these programs. It is heartening to note that the total proposed federal investment in precollege is over $660 million, and that 82% of these funds are for formal activities involving students and teachers.

This financial commitment is necessary if we wish to reform the nation's schools, ensuring that K-12 teachers are prepared to use the hands-on, active learning approach that we know is most effective in attracting and sustaining student interest in science and mathematics. Those who aspire to be teachers must be taught that way in their undergraduate courses. "Teachers teach as they are taught" is not just a cliche. Prospective teachers are greatly influenced in their approach to teaching science and mathematics by the way they were taught. This is another reason why priority attention at NSF must be given to the reform of introductory courses at the undergraduate level.

Many independent colleges graduate very high percentages of their students with majors in science and mathematics. These institutions are natural sources of a substantially increased stream of properly educated science and mathematics teachers for the K-12 level. The single most important determinant of what elementary and secondary students learn in science and mathematics is what their teachers know. Teacher preparation must therefore include substantial, deep exposure to the content of the fields taught in the elementary and secondary classrooms.

The NSF can and should make a special effort, within the framework of existing programs, to support our institutions with teacher preparation programs. Together we should reexamine the structure and content of these programs to see if a greater focus on the preparation of science and mathematics teachers is feasible, and to encourage colleges without teacher preparation programs to consider certifying precollege teachers in science and mathematics fields.

We recognize that the primary responsibility for the nation's elementary and secondary schools is at the state level. However, in this as in so many areas, the NSF plays a critical role in setting the agenda, in establishing standards, in challenging people to work together around a strategic plan. Developing connections between those with responsibilities for and commitment to strengthening precollege science and mathematics must be a long-term investment. The current NSF budget request recognizes this.

Partnerships. The fourth priority area for undergraduate programs, expanded support for partnerships among and between all academic sectors, is also one that will require significant NSF resources if these partnerships are to be most effective.

Educators at the K-16 level and researchers in academe and industry must join in new cooperative arrangements. Industrial scientists must work with college and university faculty and K-12 teachers. National labs must offer programs for students and faculty members of all educational levels, and college and university faculty members must engage in regular exchanges on research and pedagogy, and in activities focusing on enriching K-12 science and mathematics. NSF must take the lead in making private foundations and corporations active partners in these reform efforts.

The NSF has already begun to direct support within the Teacher Preparation and Enhancement program to encourage partnerships between colleges and schools. The new NSF Systemic Statewide Initiatives Program seeks to foster effective statewide science and mathematics planning. We strongly support those efforts and encourage even more aggressive action.

Most liberal arts colleges that I am familiar with have extensive formal and informal partnerships with the elementary and secondary schools in their region. The list of NSF support for Macalester, given in Exhibit II, includes several programs that link our faculty and staff to our colleagues in neighboring elementary and secondary schools.

An expanded network of partnerships would also serve to address one of the most critical need in undergraduate science and mathematics. There are few opportunities to confront the isolation felt by many of undergraduate science and mathematics faculty. Continued support for national meetings such as the recently-held colloquium on undergraduate science and mathematics is one approach; another would be to design national computer networks linking faculty wrestling with common disciplinary and curricular problems. Such networks could link women graduate students with women faculty and undergraduates, minority students with minority faculty role models. Exchanges between predominantly majority institutions and the historically black colleges and universities would prove of exceptional value to the entire educational community. Expanded support for international exchange of teacher-scholars is another dimension of partnerships that need encouragement and support.

I argue that attention to the development of such partnerships is a more effective approach to addressing broader immediate needs within the undergraduate community than the comprehensive institutional programs currently under consideration. My colleagues and I agree that some attention may need to be given to such comprehensive, institution-wide reforms in those colleges and universities with significant deficits to address. However, these efforts should not come at the expense of the broad-based, national improvements that will come sooner, we believe, from a strategy of balanced and expanded support for the undergraduate priorities described above. Present NSF mechanisms of support represent a sensible pattern; with some attention and additional support, they will continue to serve our institutions well.

CONCLUSION.

The invitation to appear before this Subcommittee asked for my views on the proposed allocations for research and education, and on the proposed allocations for support of the research infrastructure, for large national facilities, and on the absence of an allocation for the Academic Research Facilities Modernization Program.

The NSF Research Facilities Modernization Program has had a promising beginning. We understand that this program was established at the initiative of Congress, not the NSF. That the NSF has not asked for any funding for this program for FY 1992 is a mistake. NSF needs to take a consistent, long-term leadership role in the area of facilities modernization.

A better balance between support for meeting the facilities needs in colleges and universities across the country and the support for Big Science projects should be considered here. In 1990, the NSF issued a stark report estimating the magnitude of the facilities deficit facing higher education. It is impossible to imagine how this deficit can be addressed without the NSF as a major player. With its peer review process exerting quality control (eliminating pork barrel decisions), and with the leverage its support can provide as colleges seek funds for facilities from other sources, the leadership of the NSF is a crucial factor.

I urge you and your colleagues in other committees in the House and the Senate to restore this item to the NSF FY 1992 budget, with an appropriation of $50 million. This would be about one-fourth of the authorized level for this program.

My colleagues wish me to communicate our strong support for the efforts of Dr. Luther Williams in coordinating undergraduate programs more closely with research directorates; this affords much needed integration of the education mission with the research mission at NSF. We understand the rationale for having targeted funds for education within each of the research directorates, requiring that the essential link between research and education be considered in all funding decisions. However, another result of such an approach to funding, is that support for research and support for education are seen to be in competition with one another, rather than complementary. The NSF and the academic community must address this issue squarely, and ensure that education and research each receive legitimate attention and support.

Independent private liberal arts institutions such as the ones for which I speak today make a significant contribution to serving the national purpose in the area of science and mathematics. We appreciate the support from this Subcommittee in the past and look forward to working with you, with our colleagues at the National Science Foundation and in all sectors of the educational community, to address the challenges facing this land.

Testimony, Page 12
President Robert M. Gavin, Macalester College
March 12, 1991

EXHIBIT I.

FY 1985 was the first year the NSF-CSIP program provided support to predominantly undergraduate institutions for the acquisition of laboratory instructional equipment in the form of matching grants. NSF-CSIP received 1384 proposals requesting $40 million in grant support. They made 234 awards, out of the $5 million NSF-CSIP budget.

In FY 1986, the NSF-CSIP program budget was increased to $5.5 million; NSF-CSIP received 924 proposals requesting $23 million. They made 211 awards.

In FY 1987, largely by action of Congress, the NSF-CSIP budget was increased to $9.5 million (the NSF budget request was $7.5 million). NSF-CSIP received 982 proposals requesting $27 million; 337 awards were made.

In FY 1988, two-year colleges were eligible to compete for the first time; the appropriated funds totaled $11 million. NSF-CSIP received 1314 proposals, requesting $46 million in support for instrumentation; 362 awards were made.

In FY 1989, the total appropriated for the traditional NSF-CSIP program (predominantly undergraduate institutions) was $16 million. In this year, for the first time, the proposals for undergraduate instrumentation at doctoral institutions were also reviewed through the NSF-USEME Division, with $7.3 million available from Research Directorate accounts for grant awards. Over 2000 proposals were reviewed, requesting over $93 million. NSF-CSIP made 678 awards were made, for a total of almost $20 million.

In FY 1990, again USEME administered the instrumentation program for all undergraduate programs, with $15.8 million designated for NSF-CSIP from SEE/EHR and $7.4 from the Research Directorates. Approximately 2000 proposals were received by NSF, requesting over $90 million in grant support. Awards will number about 600, for a total of about $20 million.

In FY 1991, the appropriated $23 million combined the previously separate EHR and Research support for undergraduate instructional instrumentation. This combined ILI-CSIP program thus did not reflect any increase in available funds. NSF reviewed 2209 proposals requesting $96.5 million.

Exhibit II.

NSF Grants at Macalester College

Chemistry in Context: A New Initiative in Science Literacy for Non-Science Majors

The American Chemical Society (ACS) has a long and productive history of involvement with chemistry educational projects at the post-secondary level, most frequently directed at those students majoring in chemistry or other natural sciences. The Society has also been concerned about the lack of scientific literacy among the general public at large, and among college non-science graduates. In 1988 the ACS began a new curriculum initiative addressing chemistry as taught to students not majoring in a natural science, but taking a chemistry course to fulfill a general core graduation requirement. That initiative has led to the development of the textbook Chemistry in Context written jointly by six professors at the request of the Society. The ACS foresees nationwide use of the text materials, appropriate for use in one or two term courses. A preliminary draft version of Chemistry in Context is being pilot-tested during this academic year at Macalester College, Mount Union College, and The Catholic University.

Because many crucial social problems and political decisions are linked inextricably with science and its applications, it is the thesis of the textbook that participants in the political processes at all levels should be informed by an understanding of the issues involved, scientific and non-scientific. Students' scientific literacy is enhanced by doing so within the course through use of the textual issues and principles. Chemistry in Context incorporates chemical principles on a need-to-know basis as they pertain to a series of socio-technical issues related to the environment and the individual. The presentation will describe the major issues and principles covered, the rationale for selection of those topics in relation to the goals of the project, and their correlation to the development of scientific literacy among the target student population.

Resources for Calculus

Clarified, some would say restored goals in the teaching of calculus, together with the availability of graphics calculators and computer algebra systems call for the development of new materials: numeric experiments that enable students to "discover" what they have traditionally been told; problems that are not trivialized by new technology; accessible descriptions of meaningful, modern application, open ended, tractable projects for student investigation, and readings that set calculus in a cultural context. The 26 colleges of the Associated Colleges of the Midwest and the Great Lakes Colleges Association have joined forces to pull together such materials in a form useable by text and software writers, teachers, and students across the country. Funded by NSF, this project is directed by Wayne Roberts at Macalester College.

Exhibit II continued.

NSF Grants 1985-91

P.I.	Department	Year	Title/Program	Grant $
Parson	Biology	1984-85	Genetic Engineering Lab-CSIP	19,649
Whitehead	Biology	1984-85	Transmission Elec. Mic.-CSIP	50,000
Stocker	Chemistry	1984-85	High Per. Lq. Chromat.-CSIP	15,540
Mielke	Geography	1984-85	Weather Satellite-CSIP	7,572
Webers	Geology	1984-85	X-Ray Diffractometer-CSIP	40,985
			TOTAL 1984-85	$133,746
Torrey	Psychology	1985-86	Optical Laboratory-CSIP	14,045
Hornbach	Biology	1986-87	Ecological Fld Sta.-CSIP	17,773
Pitzl	Geography	1986-87	Workshop	138,187
Davis	Biology	1986-87	Research-RUI	125,444
			TOTAL 1986-87	$295,449
Hornbach	Biology	1987-88	Computer Laboratory-ILIP	41,586
Holnar/Schneider	Computer Science	1987-88	Computer Laboratory-ILIP	39,186
			TOTAL 1987-88	$80,772
Mink	Psychology	1988-89	Computer Laboratory-ILIP	13,304
Roberts	Math	1988-89	Calculus Reform-Sci. Eng. Math	62,650
Pitzl	Geography	1988-89	Summer/Teacher Enhance	19,800
Brundage	Physics	1988-89	Research RUI/REY	80,400
Serie	Biology	1988-89	Immunology Lab-ILIP	32,309
Davis	Biology	1988-89	Research-REU	8,000
Stocker	Chemistry	1988-89	GC-Mas Spec-ILIP	29,676
Hobbs	Geography	1988-89	Urban Vegetation Changes-REU	76,108
Mikkleson	Physics	1988-89	Fiber Optics Lab	26,140
			TOTAL 1988-89	$526,587
Schneider	Math/Comp	1989-90	Computer Lab-ILIP	29,800
Pitzl	Geography	1969-90	Computer Cartography-ILIP	14,333
Roberts	Math	1989-90	Calculus Reform	567,263
Webers	Geology	1989-90	Computer Lab-ILIP	31,022
Davis	Biology	1989-90	Research-REU	8,000
Haiman	Linguistics	1989-90	Phonetics Lab-ILIP	8,220
Schultz/Hobbs	Economics/Geography	1989-90	Soc. Sci. Computer Lab-ILIP	44,561
			TOTAL 1989-90	$703,199
Brundage	Physics	1990-91	Spec. Anal. of Glasses-ILIP	22,706
Craddock	Geology	1990-91	Research	21,220
Craddock	Geology	1990-91	Research-sup.	1,650
Ivey	Provost	1990-91	Research Ren. (RFO)	350,000
			TOTAL 1990-91	$395,576
			TOTAL TO DATE	$2,135,329

Mr. **Boucher**. Thank you, Dr. Gavin. The Chair thanks all of our panelists this morning.

Let's begin our questioning with that last point, and that is, the need that obviously exists for a continuation of a Federal role, through the National Science Foundation, in supporting funding for research facilities construction. Dr. Hooper, I was particularly taken with your statement, your written statement, concerning the extent of the need that exists and problems that institutions have today in getting access to other means of funding those needs.

Could you comment to this committee about those problems? Tell us about the difficulty that your institution has in getting funding for research facilities, and perhaps tie the overall perspective to what is happening in the States today, in terms of the fiscal crunch that many states have.

Dr. **Hooper**. Yes. At Virginia Tech, as probably many other institutions, we lack both space itself, that is the amount of space we have is insufficient. Virginia Tech is some 40 percent below the State of Virginia's guidelines for its facilities. The State does indeed have a very big problem dealing with the capital facilities questions, and it will be years before we feel we can catch up. That's one side of the question, and it is always paramount, because the new facilities, when they come on line, tend to be modernized, if you will.

The rest of our facilities at Virginia Tech are in very fine, stable buildings. But they were not built with even the remotest thought of what might be in them 20, 30 and in some cases 100 years after they were built. It is commonplace to assign a laboratory to a new, young faculty member and find that she or he enters the lab, sets up their equipment and finds that nothing will work.

There is not adequate electric current in the building to deal with it. The air moving systems are inadequate, so that some computers simply cannot run. There are safety and access problems with these buildings, all the way from handicapped access to other safety considerations that will often not allow us to do certain research, microbiological research, for example, if the air movement is not right. So it is a profound problem.

It is true that the State of Virginia has problems with its economic situation, but we are joined by a large number of States in this concern. The State has done, I think, its very best to try to help us. They are at the point where they cannot continue to help us. We can often leverage funds that we receive from perhaps the National Science Foundation or others, with other funds we can acquire. We can put together a modernization package for laboratories. I think that is what I would speak to.

Mr. **Boucher**. One of the things you pointed out in your written statement is that in a sense, research facilities construction is an orphan. This is the area of your activity that nobody really wants to fund. You have difficulty with declining State budgets, and getting the money that is necessary. The private sector is very interested in helping to fund programs, and will provide money for research scientists, and perhaps even for things like instrumentation, but nobody really wants to build buildings. The Federal Government has a very limited range of programs through which you can get funding for that, the primary one of which has been this National Science Foundation initiative.

So it seems to me you are stuck with a particular problem. When zero funding is requested for this program, where then do you go to get monies?

I was interested in your statement that the NSF provision of monies for this has a leveraging effect. Then I guess it constitutes something of a stamp of approval for the project itself, which then enables you to go forward and get funding from other sources, the State of Virginia perhaps, in your case, and private donors as well. That is the conventional wisdom. Are we correct in making that assumption? Does that really happen?

Dr. HOOPER. Yes, you are correct. In fact, the person, the administrator or researcher involved, if a sum of money is forthcoming for say, facilities modernization, and there are other partners in the research, quite commonly there might be an industrial partner, and State and other funds, we can often have agreement amongst the partners that if one will take up the case of modernization, the other will then assign larger amounts, sometimes, to the program side, or the instrumentation. So there is indeed that give and take amongst the several partners in research that can leverage initial money.

Mr. BOUCHER. Let me ask this question, again on the general subject to all three of our panel members. While the Administration is requesting no funding for the research facilities program, which by the way I might point out, is authorized this year at $250 million, it is requesting $50 million for a new initiative, and that is for research instrumentation. The witnesses, generally in their statements, have commented on the appropriateness of providing money for instrumentation.

I sense, however, that we may come to an either/or situation, where we don't provide $50 million for instrumentation, and provide something for research facilities, but that we may have to provide some lesser amount for instrumentation in order to provide perhaps $20 million or $25 million, roughly the current level of funding for research facilities.

What, in your view, would be an appropriate split between those two? Is it appropriate for us to be providing $50 million for instrumentation and nothing for research facilities? Is there a balance to be had between those two programs?

Let's start with you, Dr. Gavin, in answering that question.

Dr. GAVIN. Well, as you might suspect, my response to that would be all of these areas are important. But in these times, and in any times, we have to set priorities. Clearly, priorities from our perspective would be to have funding available on both what I would call the small scale and the big scale, for these projects.

The undergraduate liberal arts colleges depend crucially on instrumentation money. We are also very dependent on having ways to raise funds for modernization of our laboratories. What Dr. Hooper had to say with respect to the facilities applies at our kind of institution, too. So I would urge a balance.

I think the emphasis is a little bit on the wrong syllable in this case. I do think we need to continue these important programs and the stamp of approval that one gains by starter money, seed money through the NSF is extremely important for us in leveraging these.

Mr. **Boucher**. Dr. Langenberg?

Dr. **Langenberg**. I think I would say, Mr. Chairman, that within the context of the problem as you have defined it, there is no appropriate split between instrumentation and facilities. There does need to be a balance, as Dr. Hooper has said. The leveraging effect of relatively modest funds in a competitive program for facilities, the effect of that leveraging is very substantial.

As we consider the facilities problem I think it is important to remember that the Federal Government already has in place a program which is currently spending something on the order of $400 million to perhaps $500 million a year on academic research facilities. It is called the Pork Barrel. It is non-competitive, in the sense of the competitive program that NSF has developed. It is seen by most academic researchers as fundamentally a rather undesirable way to allocate those funds.

But at the same time, many of those academic researchers and their institutions pursue those funds because there is no alternative in the Federal Government, because there are no competitive programs. It seems to me, and I think to many of my colleagues, that as one considers appropriate balance one needs to consider the appropriate balance among ways in which the Federal Government is currently spending money on facilities.

Mr. **Boucher**. That is an interesting suggestion. I take it from that that you would nominate the National Science Foundation's research facilities program as a model by which the Federal Government generally should fund research facilities, on a competitive and peer review basis, as opposed to simply based on political clout?

Dr. **Langenberg**. Yes. I would indeed.

Mr. **Boucher**. Thank you very much. I have one additional question of this panel, and then I will yield to my colleagues.

Are there areas that you do not see highlighted in the National Science Foundation budget request? What priorities do you think exist today that are not being responded to through this budget recommendation? Any of the panelists who want to volunteer.

Dr. **Langenberg**. If I may, there is an area that is being responded to, but I do want to underline it. It was mentioned by Congressman Roemer when he said that at Notre Dame a building is being wired, so to speak, with optical fibers. You are familiar, I am sure, with Senator Gore's bill, S. 272, which among other things calls for the establishment of a National Research and Education Network. That's a multi-agency initiative, but the lead agency would be NSF.

I would comment only that there is something very much like a revolution going on in the scientific research community. It is a revolution that has been generated by the tools that modern information technology has placed in our hands. It has profound implications and consequences. The development of such a network, and of the means by which institutions of all kinds can couple to it, promises to profoundly affect, positively, both our scientific research and our education, in science and education.

We are talking, in effect, about an interstate highway system which will bring together not only major research institutions, but colleges and universities of all kinds, public libraries, elementary and secondary schools, students at all levels. The potential of that is just absolutely amazing in many ways. The fiber optic networks that Notre Dame is installing can be considered the equivalent of the old farm to market roads. The Federal Government built the major highways. The States built the State highways, but if you really wanted to get products in from the farms to the market, you need to have the county roads. And those needed to be built by local jurisdictions.

Mr. **BOUCHER**. Thank you, Dr. Langenberg. I might comment that this subcommittee began the process of assembling legislation on that very front last week, when we had a very lengthy hearing. Senator Gore testified, and we examined aspects of the House companion to his legislation. I expect to have further proceedings on that in the very near future.

Dr. Gavin or Dr. Hooper, would either of you care to comment?

Dr. **GAVIN**. I would like to say that my concern is the rate at which we are recognizing in our budget structure what I think is the consensus around the country with respect to education. That is, that it is a continuum from elementary, secondary, through the collegiate level. My concern is that we are still talking in many ways about balancing things between research activity and teaching activity or education.

My major concern is not with particular programs, but with an overall bias that I think in the long run does not serve the country well. That is, support for precollegiate education and the leadership that the NSF can play in that area is extremely important. It is also extremely important at the undergraduate level.

So my concern is not so much that there are things left out, but that there are things that are not said that ought to be said with respect to that importance. When it comes down to the dollars, that is making a statement about relative importance. I think the leverage the NSF can have overall in education is tremendous when one looks at the elementary, secondary and undergraduate levels. So those are my concerns.

Mr. **BOUCHER**. Thank you. Dr. Hooper?

Dr. **HOOPER**. I certainly would support both Dr. Langenberg's and Dr. Gavin's points. Let me comment a little on one that I am particularly interested in in my role as Dean of the Graduate School. I think if we were to talk with all the professionals, including those at academic institutions and government labs and others, we would find that they had been touched in some way during their development by National Science Foundation or other Federal research and fellowship support.

We created that cadre of people who have made the system we have now. I am concerned with putting something into the cupboard for the future. The availability both of the individuals brought up through this system and then that funding to finish them and bring them to the point of being those professionals, is a great concern that I have, and I think others in the academic institutions have right now.

Mr. **BOUCHER**. The Chair thanks the gentleman, and recognizes now the gentleman from California, Mr. Packard.

Mr. **Packard**. Thank you, Mr. Chairman. Dr. Gavin, in your testimony, you have recommended that the course and curriculum effort be doubled. Where would you suggest we come up with those additional funds?

Dr. **Gavin**. From my remarks before, I implied the question was really a matter of emphasis. My feeling is that if we are going to get the kind of leverage and results we need, more emphasis has to be placed on this curricular area. Where would it come from? Well, I think it comes from how much we can do in terms of big science projects and in fact a relatively small fraction of the big science project would completely fund all these activities we are talking about.

Another possibility would be to avoid a dichotomy between big science and small science, and to find ways, in our big science projects, to have this kind of educational effort linked to it. I think that might be a more creative way to go, and one which in the end gets us more for our public dollar.

Mr. **Packard**. Also, Dr. Gavin, in the last eight or more years, we have tried to give significant emphasis to improving our science and math and instructional programs in those particular areas, and in languages. Yet, it does not seem we have made the kind of progress we had hoped for when some of the new programs came out in the past few years. Of course, in your testimony you have emphasized that area also. What can we do to balance ourselves out of the doldrums in this area?

Dr. **Gavin**. I think there are a number of things going on now that will provide results 10, 15 or 20 years from now. Dr. Hooper's comment before about the scientists who have been productive over the last 15 or 20 years, many of us benefitted from NSF programs. Without NSF programs and without those initiatives, we would not be where we are today. I think there are a number of programs that are already showing success, and I am most familiar with the ones at the undergraduate level.

I would say those programs that have been most successful are the ones that have gotten us back to dealing with scientists and experimental, laboratory based systems, rather than removing the students from the laboratory. I am not an expert on the precollegiate level, but it is my impression that at the precollegiate level, too, greater emphasis on the involvement of the students with experimentation is already showing results. It takes years to turn it around.

There are other social factors involved. We certainly need to do a better job of providing opportunities and progress for women and minority scientists. There is no question about that. The societal changes, along with the educational changes, I think are beginning to have effect. But we are a long way from where we ought to be.

Mr. **Packard**. Dr. Hooper, you emphasized in your testimony the use of private funding. Would you elaborate on that a little bit—what you recommend and what you have done to enhance private funding for some of the programs we are discussing this morning?

Dr. **Hooper**. I might use as an example our National Science Foundation Center and polymeric adhesives. The basis for this program is that the University has the capacity to do continued and fundamental research. We need to support that starting point. Industry does have a shorter-term interest, most often.

But we have found it quite common at Virginia Tech, and readily acceptable to industry, to work with them to match up with particular interests of theirs that fit with the fundamental work we are doing with the training of our students. We have probably more dollars for sponsored research at Virginia Tech from industry than any other single feature of the University, including any of the Federal agencies.

Mr. PACKARD. Do you feel you could develop a model from your experience that would be useful to other universities in terms of enhancing and developing private sector funding for research?

Dr. HOOPER. We must confess that we have turned to our colleagues at other universities and borrowed from them good ideas already. We have developed some at Virginia Tech that are being looked at. We constantly have that exchange, and the network spoken of by Dr. Langenberg is one of the ways. Those faculty members sit at their desks with terminals and exchange information on how they affected this relationship, or what happened in a situation, and so on. So that is a common thing.

Mr. PACKARD. Dr. Langenberg, you emphasized research. It is not easy to develop a balance between the funding for research and the funding for some of the other programs that we are also seeking additional funds for. How do you recommend we come to a balance, and what can be done to give appropriate emphasis to research, which I think we have neglected over the last several years, recognizing that there is some competition for the dollars?

Dr. LANGENBERG. I think the only way you can develop that balance is to rely upon the judgment of the full community of educators and researchers, then to draw upon that advice to exercise your own judgment about that appropriate balance. That is the process you use, a process that we have historically used in this country. I know of no better process.

In respect of the balance between funding for education and for research at NSF, we must be aware of the critically important need to make sure that there are enough researchers, that there are enough technicians and enough scientists and enough engineers in the next generation. At the same time, we have to make sure that when we bring them through our school system, and launch them into their careers that there is in fact funding which will support their commencing a research career, a viable research career. Picking that balance is a very difficult task, but it is a task we all share. There is no other way I know of except to use our best judgments.

Mr. PACKARD. Is the private sector doing their share of research, or is the Government doing its share?

Dr. LANGENBERG. I think one could argue that the balance in this country is not bad. It may not be optimal, but it is not bad. Both the private sector and universities funded by the Federal Government carry on an important amount of basic research. Universities tend to perform most of the basic research, but industry performs a considerable amount, as one moves through the spectrum, through applied research and then development, industry takes on a larger and larger role. I would say the present general balance is not so bad.

Mr. PACKARD. Does the university benefit sufficiently from their research, or are those benefits generally passed on to the private sector in greater proportion than what is in the best interests of the university research?

Dr. LANGENBERG. Well, I think universities would always like to benefit a little more than they do, regardless of circumstances. But again, the benefits are, I think, distributed reasonably well. The question of benefit, financial benefit, from inventions for example, that arise in the course of research, is an interesting one.

You will note in my written testimony that Professor Mansfield has, through careful economic studies, estimated that the total societal rate of return, the annual rate of return on investment on academic basic research is 28 percent or so. That's an enormous rate of return. I wish we could all get that from our personal investments.

How much of that accrues to the universities and the researchers? I would guess probably at best something on the order of one or two percentage points, and that only in institutions that have very highly developed patenting and licensing operations. But I am not sure that one could or should increase that much further. The benefits must ultimately accrue to all of the institutions that are engaged in the process of development, creating knowledge and turning it to useful ends.

Mr. PACKARD. Thank you very much. Thank you, Mr. Chairman.

Mr. BOUCHER. The Chair thanks the gentleman and recognizes the gentleman from Arkansas, Mr. Thornton.

Mr. THORNTON. Thank you, Mr. Chairman. Let me compliment the witnesses on their testimony.

I was struck by a quote within a quote, Dr. Gavin, quoting James Powell, President of Reed College. In a recent address, he says that a useful step would be to "require each big science project to have a plan showing how it would help to improve the state of the human and physical resources of the Nation's science base." Then he quotes Frank Press as saying that "the highest priority has to be people."

Ultimately, that's where the human intellect and science comes home, not at institutions, not in a facility, but in the working of a human mind. It seems to me that we must keep constantly aware of the fact that mental achievements must be shared widely through this Nation.

I commend you for your emphasis on the undergraduate role of institutions such as yours, in providing for knowledge of science, not only among those who become experimenters and researchers, but those who become policy makers, those who enter other fields but need to know. As Dr. Luther Williams, whom you also quote, so often emphasizes, science must be shared broadly across this Nation if we are to build upon a base of knowledge of science, the kind of excellence we try to achieve.

It seems to me you also are correct in suggesting that we sometimes look only at the top of the tree, as we examine the results of science. If I may reminisce, Mr. Chairman, a few years ago, I was sitting here in this committee room with Dr. Atkinson, who was then head of the National Science Foundation. We were talking about the research share of different institutions.

I was sitting there in the Chair's position, and asked Dr. Atkinson how much the State of Arkansas received for scientific research. He said "Mr. Chairman, I don't have that figure at hand, I will be glad to furnish it to you after the hearing is over."

We proceeded, then afterwards he came up and said "Mr. Chairman, I knew exactly how much Arkansas had, but I didn't want to put it in the record. You see, your state is not much of a player in the scientific apparatus." I said "Well, we have some smart people out there." He said "Yes, but they don't know how to write grants."

So out of that conversation, with the help of Jack Talmadge and others, we developed the Experimental Program to Stimulate Competitive Research in science, and to recognize that science did not necessarily have to be accomplished at MIT or Stanford, but could occur all across the Nation. Now that program, after initial objections that this was pork barrel, but it wasn't, it was peer review. It was excellent science.

At the University of Arkansas alone, Dr. Lothar Shaffer won a national prize for an electron defraction analyzer. The other two colleges and universities which shared in that prize were Stanford and MIT, who I just mentioned. Not as a participant in the export program, but because of the effects that program had on science, the Wall Street Journal a few years ago remarked upon the remarkable achievement of Drs. Allen Herman and Langzhi Sheng, at the University of Arkansas, in developing the world's highest temperature superconductor, a pallium based compound which still holds the world's record for high temperature.

My point is that let us not ever think that we can target specific institutions and flow all of our scientific research funds towards those institutions. But it must be part of our objective to make sure this Nation has the kind of scientific base which liberal arts colleges, high schools and others— and I commend the NSF for recognizing this. Dr. Gavin, my question to you is, do you think that a larger role should be allocated to the liberal arts colleges in achieving the kind of scientific base I have been describing?

Dr. GAVIN. Yes, I do, and let me tell you why I think it is extremely important that these colleges play that role. We think we have a record of demonstrating that we can produce scientists in numbers which are much larger than many people are aware. We have a relatively small percentage of the undergraduates in this country, yet we consistently produce a very large fraction of the Ph.D. scientists and engineers. The emphasis at the undergraduate institution is in broad- based learning and we are educating kind in the basic sciences.

In the State of Minnesota, the liberal arts colleges have 18 percent of the undergraduates. We produce over 50 percent of the majors in chemistry and physics and biology and mathematics. We also produce a number of people who go on to be policy makers. Those kind, at a liberal arts college, must take science. In fact, they must take laboratory science. So we feel that the role we play is extremely important.

I mentioned earlier the importance of precollegiate education. We feel that the entire system needs to have attention. And we also feel that very good science can go on at small institutions. I could mention several small institutions that have scientists who have received national awards for the work in basic research. We also fully support peer review and competition. We do not want a special setaside so that we don't have to compete for it.

Mr. THORNTON. Absolutely.

Dr. GAVIN. That is a very important part of our system, and we think it strengthens and strengthens the whole system.

Mr. THORNTON. Is this not also true within some area of comparability with the historically Black institutions? I know Dr. Charles Walker is frequently consulted on scientific programs, and seems to be doing a good job of developing them. Is this a correct statement?

Dr. GAVIN. Yes, it is. In fact, recently the National Science Foundation has supported a study of undergraduate education and what works, involving liberal arts colleges, historically Black colleges, and we have recently had a conference at the National Academy of Sciences on this particular topic. We have emphasized the key elements of what has been successful at these institutions. Historically Black colleges have produced a very large fraction of our scientists.

And Black colleges support the same philosophy I talked about before, that is creating this community of learners and support at the undergraduate level, involvement in research, moving on then to graduate programs.

Mr. THORNTON. And Dr. Hooper, has it been your experience, sir, that people have come from some of the undergraduate institutions and moved on into the higher educational requirements of graduate study, are they well prepared? Is that a good field from which to recruit excellence in science, as you proceed to the doctoral levels?

Dr. HOOPER. Since I came out of that same environment and Dr. Stout, who joins me—

Mr. THORNTON. I didn't know that, sir.

Dr. HOOPER. We came from a liberal arts college, yes, we could speak to this sort of seamless idea for all of us in the educational community.

Mr. THORNTON. And that is really what I want to address to Dr. Langenberg. It is a seamless web, is it not, sir, and the health of our scientific community must span all elements of education?

Dr. LANGENBERG. It is most certainly so, sir, and if I could just comment on a couple of your points. By historical accident I had the honor of taking to the National Science Board the first round of EPSCoR grants, and have a been a strong supporter of that program ever since. I think the evidence is clear, that the historically Black institutions and the liberal arts colleges of this Nation have done more than their share to prepare those scientists that have made us the wonder of the world.

You will find that the incoming director of NSF is a product, at the undergraduate level, of such an institution. Finally, I would remark that one of the enormous virtues that I see in the proposed National Research and Education Network is what I have called in my testimony before the Gore committee the "democratization of all human knowledge." It will make the full array of human knowledge available to everybody throughout that seamless web of institutions, from the freshman at Macalester through the senior scientist at Berkeley.

Mr. **THORNTON**. Thank you very much, Dr. Langenberg. Thank you, Mr. Chairman.

Mr. **BOUCHER**. The Chair thanks the gentleman and recognizes the gentleman from Illinois, Mr. Fawell.

Mr. **FAWELL**. Thank you, Mr. Chairman. I apologize for being so late.

I have just one inquiry. That pertains to graduate degree programs for high school and middle school science teachers. Not too long ago I had occasion to meet with several science teachers in our high schools in the western suburban Chicago area, which basically have some very, very fine high schools and middle schools.

One teacher related to me that he and a number of his colleagues had used the summer scholarship programs at NSF back in the 1960s, and I guess it tailed off and died around 1973. He indicated he felt this was invaluable, and that within the next 10 years a lot of these teachers will be retiring. There is, especially in areas in downstate Illinois and rural areas, you may find a lack of expertise, a biology teacher that has to teach physics, and things of that sort.

He asked the question why was that program discontinued, with the emphasis now being more on workshops for teaching techniques and education teaching? I did not have a real answer for that. I have made some inquiry at NSF. But I would be interested in the viewpoints of any one or more of you in regard to what you think of such graduate degree programs for the teachers in high school and middle school who really have the capability of exciting the students when they have to be excited, or they won't even be at the liberal arts schools or anywhere else, looking at science. They would have chalked that off long ago.

What do you think about graduate degree programs, and are we following through there to the extent we ought to be?

Dr. **HOOPER**. If I can make just two comments, the Commonwealth of Virginia and Virginia Tech are now involved in enhancing the subject matter training of both those who are going to be the new teachers, and working cooperatively with teachers in place. They do have a formidable challenge, to instruct, and they need that help. We offer special tuition discounts to educators who wish to come back for graduate studies and try to make things as good as possible for them.

Dr. **LANGENBERG**. Congressman, if I may suggest a couple of things. I am not sure that a graduate degree program is really what is needed to support elementary and secondary teachers in becoming better able, really, to make science and mathematics exciting to students. There are a number of examples around the country that I think are very promising.

As you know, that same Dr. Leon Lederman that I mentioned earlier has been very active in the Chicago area, in creating an Academy, if you like, for the teachers in the Chicago public schools. In Maryland, Governor William Donald Schaefer several years ago created a Governor's Academy, which exposes elementary and secondary teachers each summer to an intensive six-month experience with real math and real science as it is currently done. This takes place at several institutions of our University of Maryland System.

We have recently been working with a major industry, a Maryland industry, to build on that by providing a means to support the teachers in carrying the gospel they have acquired during those summers to their fellow teachers throughout the year.

These things really do work. When I attended the graduation ceremony last summer for these teachers in the Governor's Academy, I found a group of teachers who were more turned on, who were more excited by what they had learned and what they were now able to teach their students than any other group of students I had seen for years.

Mr. GAVIN. There is a also a role the undergraduate liberal arts colleges are playing in this area. Let me give you a couple of specific examples from what we have done at Macalester, and I think it has had a very positive impact.

Research activities are one part of renewing and expanding the perspectives of the teachers. We have had secondary teachers who have spent a year at Macalester in a program which involved them in laboratory teaching, involved them in cooperative research with our faculty members, involved them in senior research projects with our students. The objective was to allow them to take advantage of the opportunity to work with some of the instrumentation we have been able to get through the NSF instrumentation program and to see how curriculum development has gone on, and at the same time to get some experience in research.

So I think the opportunity ought to be available and ought to be expanded for people. I think there are a large number of institutions that can benefit from this. We benefitted tremendously from getting an excellent high school science teacher involved in our instructional program. So each institution benefits from it.

Mr. FAWELL. I am sure all those programs are extremely worthy, and I am very familiar with Leon Lederman's program in the inner city of Chicago, for instance. That is near my district in the western suburban area. We have the Illinois Math and Science Academy. But there seems to be, as was expressed at this particular meeting, you can't teach what you don't know.

Again, as we go into the rural areas, it is hard to excite teachers, or even get them to go to labs to learn lab techniques and things of this sort, if you basically don't have the foundation. Their feeling was that by not offering the summer scholarship program, it might take three or four years to get a graduate degree, and give to that teacher a feeling of in-depth competency.

In our area, they can go to FermiLab or Argonne or tremendous groups of that kind that are doing a number of things to excite teachers about what they call "weird science" with all the bells and whistles that will excite kids, and all these techniques. But consistently they came back and said there is a lack of high school teachers and middle school teachers. Everyone who was a part of this particular meeting said that it was too bad NSF had dropped the concept of offering these graduate programs, where they can pick up degrees and pick up competency.

One of the problems is to get them to stay in their field for at least two or three years afterwards, some I guess, in the past have tended to opt out and go into industry once they have that competency. But I thank you for your views. I am going to do a little persisting with NSF to see if the additional funds that are available, all of which I am sure are planned to be spent right now—but that we think in terms of looking at those summer scholarship programs.

Again, it would help the biology teacher who has been told he is the physics teacher. He does not have the expertise, I suppose, to even pick up a lot in the lab programs that you might offer, because he basically can't teach what he doesn't know.

I thank you for your views, and I will continue to sniff around and see what I can do in this area.

Thank you, Mr. Chairman.

Mr. **Boucher**. The Chair thanks the gentleman and recognizes the gentleman from Florida, Mr. Bacchus.

Mr. **Bacchus**. Thank you, Mr. Chairman.

Gentlemen, I want to congratulate you on your testimony and thank you for taking the time to be with us. If I had my way I would spend a lot more money on scientific research and a lot less on some of our other less productive endeavors. However, I have just one vote. We have limited resources, and it seems to me we are going to be fortunate if we are able to get the President's request through. I applaud him for requesting the increase that he has.

Given that, it seems to me we need to focus on the basics in terms of what we need to prepare for our future as a country. First of all, I think we need the right instruments and facilities. We have discussed that. I share your concerns there.

Second, it seems to me we need to invest in the right people who are doing the research. Third, we need to invest in the right kinds of research. And fourth, we need to have the right kind of regulatory atmosphere, that can make the research possible and profitable.

With respect to the second of those four points, Dr. Gavin, you have spoken eloquently and persuasively about the importance of a liberal arts education. Since I have one, I agree with you. Sometimes policy makers do emerge from ninth grade chemistry students who break test tubes. There is a gentleman named Tom Barnes at Lyman High School in Seminole County, Florida, who can tell you that. He is much surprised at my presence on this committee.

My question is, would you agree that not only do we need to expend more of our emphasis in finding the right people in the liberal arts colleges in which to invest, but also that we need to focus more on some of the smaller four-year state universities and the community colleges?

Dr. **Gavin**. My opinion is, and it is probably easy for me to say, coming from a liberal arts college, I think the reason we are so successful at the undergraduate level in science is that there is much more of an emphasis on undergraduate education at an institution where that is the only game.

So I fully support providing more opportunities for programs involved in all of the other higher education systems to compete for funds that will support that undergraduate activity. I think that undergraduate activity is crucial to support the graduate activity. Many times the reward system is set up at the larger systems, and not just by the state system itself, but by NSF programs and other programs, so that a faculty member is really penalized by attempting to do something in this undergraduate area.

I think the National Science Foundation can aid in bringing what I would think a more appropriate balance in terms of opportunities for faculty members to play in education at the undergraduate level by having increased funding in this area.

Mr. BACCHUS. You were also eloquent in talking about the contributions that have been made by our predominantly Black institutions. I agree wholeheartedly with the comments made by my colleague from Arkansas, who I much admire. Do you feel the National Science Foundation has done enough to encourage Blacks and other minorities to get involved in science and science education?

Dr. GAVIN. I think the National Science Foundation has had a number of very good programs. I think the support they have provided at historically Black colleges has been a very important element in their success. I think those institutions which are not historically Black institutions need to do a better job in educating minority scientists and women.

I think the efforts at the National Science Foundation to provide us with support to make changes which will allow us to be much more successful in this area are very important. So I think there is an ongoing effort. Historically Black colleges have done a much better job with the resources than the other colleges.

Mr. BACCHUS. I would certainly hate to miss an investment in the next Galileo simply because he or she happened to be at some place other than Harvard or Yale.

In addition to the right people, it seems to me we need to fund the right kind of research. I think it was Lord Kelvin who said that if governments had been funding scientific research during the Stone Age, then today we would have a lot of wonderful stone machines, but no metals. Are we directing our money in the right kinds of places?

Dr. Langenberg, I was very impressed with your statement about the democratization of human knowledge and the potential for the new highway of supercomputers and the network we are contemplating. We had hearings on that bill last week.

Are we making it possible not only for the establishment scientists to get funding but also those mavericks who might have that idea that might change the future?

Dr. LANGENBERG. For the most part, I think NSF and the scientific research funding agencies in general are doing about as good a job as we know how to do. That does not mean we are never going to miss a maverick genius, but by and large our system is so diverse, there are so many sources of funding. There are many agencies that fund research and academic institutions of all kinds. There is no single ministry of science and technology in this country which decides to build an ever larger and more complex stone machine.

By and large, it is a very diverse system. We also have this incredibly diverse array of academic institutions, liberal arts colleges, community colleges, four-year institutions of all kinds, the great research universities. The very diversity of that system, it seems to me, makes the maximum possible opportunity available to everybody with the will and the ability to be that outstanding scientist. I would not know how to do it better.

Mr. BACCHUS. Finally, sir, my fourth point about the need for the right kind of regulatory atmosphere. Thank you for sharing the article from Science magazine with us, the survey conducted by Dr. Lederman. In that survey, the point is made that the regulatory atmosphere for scientific research is increasingly confining. Could you elaborate on that and perhaps suggest some ways we might want to consider changes in this regulatory atmosphere?

Dr. LANGENBERG. Let me begin by saying that most of the new regulatory structure is there for very good reasons, and represents a real need for regulation, oversight and accountability in general. Examples would be the regulations that control the use of human subjects in research. Obviously, clinical research in the biomedical sciences in the end must address the mammalian species to whom all that research is directed—people, human beings. You have to do research with human beings. At the same time, you must protect them from unnecessary risk.

The same is true of the use of animals in research. Likewise, research that uses hazardous materials must be regulated. Researchers use an incredible variety of materials, and as we discover more and more about them, we are beginning to discover that—this is a bit of an exaggeration, but not too much of an exaggeration— practically everything is hazardous.

There are the necessary financial controls. The Federal Government spends an enormous amount of money on research in a huge variety of institutions. The people of the United States and the elected representatives and the executive branch need to insure that these funds are being appropriately spent.

So all of that regulation is appropriate, is necessary. I think what probably is correctable, or adjustable, is some of the nature of the regulations. We have become a very risk averse society. We have implicitly adopted the notion of zero error.

When confronted with the occasional error, the occasional mistake and the occasional problem, our tendency is to write yet another set of regulations that will close down the opportunity for that, to create multiple levels of approval, of responsibility, to create situations in which someone has oversight responsibility, and then we provide watchers to watch the someone and some watchers to watch the watchers. Before you know it, we have brought into being an enormous administrative lattice, parts of which are clearly unnecessary.

The fundamental issues that have brought some of that lattice into play are necessary. They are important. But quite frankly, I think everyone's experience is that we have gone overboard in many respects.

Mr. BACCHUS. Dr. Langenberg, I agree with everything you have just said. Those regulations are important. It is important to protect those things we are trying to protect. But I believe it is incumbent upon those of us who serve the people in positions of responsibility in the Congress and in the Federal Government to always be mindful of the cumulative impact of all these regulations on what we are hoping to accomplish in the first instance. I think we forget that too often.

In addition, I agree with you wholeheartedly about our tendency to try to minimize risks too much. Certainly we need to be careful in the way we live. But I think we have achieved much of what we have achieved as a civilization because of our willingness to take risks.

Thank you, Mr. Chairman.

Mr. **Boucher**. The Chair thanks the gentleman and recognizes the gentleman from Iowa, Mr. Nagle.

Mr. **Nagle**. Thank you. I apologize for not being here earlier. This is frankly a major concern to me. I have the distinct pleasure of representing two universities with a combined undergraduate enrollment of 40,000 students, three private colleges, including Grinnell, Wardberg, and Luther, and three community colleges. I joined two other private institutions. I joined another university, a Big Eight school, and three other community colleges. So I have a great deal of interest in this, because of the nature of my constituency.

But I would like to probe something. I am very, very cognizant of the testimony that a student enter a Wardberg, or Luther, or Grinnell, is much more likely, if they are science, to be able to complete that with a B.A. or B.S. in math or science than they are if they go the University of Iowa or any of the schools we see on T.V. on Saturday afternoons.

Yet I am also told by many in the academic community, that "Congressman, you have to reserve the peer review process. It is absolutely essential that research grants be funded only on the basis of academic merit as decided by experts in the field." I am trying to reconcile how I split up the funding, if I am true to peer review, against the obvious need to encourage undergraduate research for undergraduate students who actually have a chance for a hands-on position, which is much more likely to take place at those smaller colleges.

I wonder if you could comment on that. I keep getting hit constantly about maintaining the peer review. They don't want me involved. They don't want pork-barrel research projects.

But on the other hand, if we stay pure peer, then we obviously are going to keep funding the larger institutions to the expense of the smaller institutions that are doing the undergraduate. I am just curious as to how I walk that line, in terms of funding and approach.

Dr. **Gavin**. I have some suggestions.

Mr. **Nagle**. That's why I asked.

Dr. **Gavin**. As a scientist who for many years was constantly seeking support for research activities as well as teaching activities, I think it is extremely important that we stick to a peer review system. That peer review system is our strength. That provides the quality control, that provides the competition, that provides the review. I would say that faculty members at liberal arts colleges as well as at universities learn almost as much from being turned down in a peer review as being successful.

That may sound like a startling statement, but when we are talking about many of these research activities, the new ideas, the new discoveries, the creative thoughts many times come because of the opportunity to compete and to have others criticize your work. So I think peer review is an essential part of the system.

With respect to undergraduate research activities and research activities carried out on liberal arts college campuses, as opposed to large research universities, I see no reason to give up on peer review and say there should be no peer review at the undergraduate institution whereas there should be at the graduate institution. I think that's the wrong direction to go.

Mr. NAGLE. Would you throw your funds into categories, through? Would you segregate your funding mechanism so much in undergraduate and so much for graduate?

Dr. GAVIN. Yes, I would segregate by sector a little bit more though the sectors overlap. I think undergraduate research activity is just as important at the University of Minnesota three miles down the street as it is at Macalester College. So I think the question is whether or not there is support for education at the precollegiate, the undergraduate level, and the graduate level, and then within those systems to have a competitive system.

Mr. NAGLE. Educate me, will you, is the current funding mechanism currently segregated or are they all lumped into one for research?

Dr. GAVIN. There are many activities that combine. In my earlier statement I emphasized the importance of continuing in that direction. That is linking research and educational activities. There are many programs at NSF now that do that, and there are opportunities for one to speak to, in their research program, how they are providing education and moving people ahead and developing new scientists.

So there is a cooperative program. There are a number of programs that went through an alphabet soup of different programs that we are very enthusiastic about at liberal arts colleges, because there is an undergraduate research component and there is an opportunity for training as part of the research program. I think that is a good policy initiative, a good policy direction and one that ought to be continued.

Mr. NAGLE. Should we as a Congress be more proactive in terms of seeing that this balance, segregation of funds between those two functions of NSF takes place, or should we trust the agency to continue to do it? I am very, very concerned, when we are not producing the number of Ph.D.s. in math and science in this country that we are obviously going to need in the year 2000, and the current system does not seem to be producing them. The Japanese are producing almost twice as many as we are, at half our population. Half our Ph.D. candidates, frankly, are foreign nationals. There is nothing wrong with that, but that even cuts our number by half again.

Dr. GAVIN. I think the strength of our system is that we have open public debate of these issues. I think the Congress is playing just the role it ought to be playing and this committee is playing just the role it ought to be playing, but having open public discussion of this. The representatives of the National Science Foundation are involved in the dialogue. Representatives from colleges and universities are involved in the dialogue, and I think that's the best way to carry out the process. You become informed when you pass that legislation.

I don't want to characterize people as having more or less emphasis or effort in a particular direction. I think the important thing is this open public dialogue we are having now.

Dr. **Hooper**. If I could add support for this viewpoint, let me point out that we have a complexity of undergraduate education that is very good for the Nation. At the liberal arts institution, which I attended, I had a certain opportunity for research and a very sound education. At the one where I am now employed, the undergraduate student has a very different opportunity than they do at the smaller institutions. It is good, and we should encourage it as well, with support for undergraduate research and training at the large institutions.

That complexity of opportunity that you have at the big institution, with the broad range of disciplines, with the large faculty, with the excellent research facilities, and with graduate students who often serve as mentors and informal advisors in research, I think supports what we have going on in the liberal arts colleges as well.

Mr. **Nagle**. To play the devil's advocate, however, it does not seem to me that the present system is getting the job done. If the statistics I cited are accurate, and I think they are, I think there is at least four times better chance if I go to Macalester than it is if I go to the University of Iowa, pick my own schools. I have a one in 17 chance if I go into the University of Iowa, of getting through there with a B.A. or B.S. in science or math.

My odds of doing that at a smaller college are quite dramatically different. Obviously, they have more undergraduate science initiators, majors, start that at the larger universities, but they don't seem to be getting through the pipeline. It seems to me if we just perpetuate what we are doing, then in five years we are going to be saying "Gee, we are not getting the job done." I would just like your comment on that. To me it does not seem like the present system is doing the job it needs to be doing.

Dr. **Hooper**. I think my earlier comments today were very supportive, of all the way from kindergarten up, having this emphasis. We recognize that the large institutions, that indeed all the product is not forthcoming in terms of human resources. We have to look at ourselves, and we are currently looking and adding greater emphasis to our undergraduate experience. How long they are here. Why they are here that long. There is a good deal of introspection at the large universities on that subject. It is healthy.

Mr. **Nagle**. What kind of lethargy, if I could use that term, set upon the scientific community to where I am told the new initiative in science is for scope, a different type of curriculum than we have had before? I am told in math the new criteria they are attempting to reach is called standards. I think I buy those efforts, but I do want to ask where they have been for the last decade? Why are we doing it now in 1992 after the horse is out of the barn?

Dr. **Langenberg**. Let me try to respond to that, Congressman. I think it probably is true that there has been pretty much throughout the last decade a greatly renewed interest in undergraduate teaching on the part of academics at major research universities in all disciplines. Within that, I think there has been a strengthening of a continued interest in the scientific community and how we educate not only those who are going to be scientists and engineers, but the general public as well.

Some of that increased interest I think is traceable to the substantially enhanced funding for and support for NSF's science and engineering education activities that has a large part of its basis in this committee. An example, that I would give is Project 2061. This is a project that has received NSF funding and substantial private funding. AAAS has sponsored it. It has a rather ambitious goal, nothing other than the total and complete reform of all mathematics and science education for all Americans, primarily in the elementary and secondary schools. It is a very long-term project. Its time horizon is something on the order of 10 to 15 to 20 years. That reflects something that Dr. Gavin said earlier, as one contemplates training a human being, beginning at the age of six or seven and producing ultimately perhaps a post-doc in chemistry at the age of 28 or so. You have to be patient.

That program really got going about three or four years ago. It passed through a definition phase in which the task was to define just what it was that all Americans should know about mathematics and science. That phase involved the participation of probably 400 to 500 scientists, engineers and mathematicians all across the country. It was completed, I think, very successfully. The program is now in a second phase, in which the results of the first are being turned into some real functional, programmatic curricula and materials by teachers, elementary and secondary teachers at a number of sites around the country.

That phase, if all goes well, should be complete in another couple of years, and then comes a phase that will last more than a decade, which we hope we can transfer this new knowledge into the transformation of all American elementary and secondary math and science education. That bespeaks a very strong involvement on the part of the American scientific community. It has been active. In fact, rarely have I seen so much ferment in that community over the question of educating undergraduates and elementary and secondary students as I have seen recently.

Mr. NAGLE. I don't mean to beat a dead horse, and I don't mean to be hostile, because it is obviously not your fault. And you are frankly easy to fund this year, because everybody is so impressed with what our weapons systems can do that science is in again.

But I worry that the almost cocoon-like state that the promotion of science, scientists and science education and math and engineering went through a decade ago will return almost immediately upon the public's losing fascination with the current round of electronic weaponry. I don't want us to make the mistakes three years down the road that we have made in the last 10 years.

I would be interested in your recommendations in terms of how we avoid that. We just let science drop off the radar screen in this country. An MBA was much more popular than what a Ph.D. in math was. I don't want us to go back, once public fascination with current technology fades, as inevitably it will, because the public does not maintain that kind of focus for very long on any particular topic. How do we avoid, in the next five years—it is easy this year. I am not concerned this year. But how we do avoid going back to where we were starting in about 1982 and coming forward?

Dr. LANGENBERG. Congressman, I agree with you that we need to keep these issues before the public. I am afraid that having lived through two or three or four cycles of surges followed by declines in public attention to these issues, I am not terribly sanguine about our ability to maintain a steady level of public interest. The great Sputnik event was a major event in my early scientific life. It occurred when I was in graduate school. I have seen at least two or three cycles since then.

I don't know any simple way to avoid them. I think this committee, my association, the American Association for the Advancement of Science, and every single academic institution represented here can play major roles in keeping public attention focused on these important issues. But it requires continuous effort.

Dr. GAVIN. I have a few comments to make. I too was thinking of Sputnik. I was in high school at the time, and I know the tremendous impact that had on my high school science, on my undergraduate science, on my graduate science. National Science Foundation and Iowa State University provided me with my graduate education.

Mr. NAGLE. You understand that's not the one in my district.

Dr. GAVIN. I understand that. I understand the difference between the Big 10 and the Big 8 and the Hawkeyes and the Cyclones.

Mr. NAGLE. You function well with a second class education and a second class football team.

[Laughter.]

Dr. LANGENBERG. I should interject, Congressman, that I am a member of the Iowa State undergraduate class of 1953.

Mr. NAGLE. With apologies. Where did we get this panel?

Dr. GAVIN. I think it only underscores the important issue of diversity, though. The kaleidoscope of various possibilities we have in education I think is a strength in this country. One of the things I think was important out of the Sputnik era was a recognition that science education was extremely important, from precollegiate, collegiate and graduate.

My own feeling is, getting back to some of your earlier questioning, my feeling is that we drifted in the direction of concentrating far too much on just the graduate portion of that. I think that's extremely important. But if we forget about the undergraduate and precollegiate area, we are not going to be able to make progress.

We think we know, at small colleges, why it is three to ten times more probable that one will finish an undergraduate science career at our colleges rather than at some of the larger universities. We don't blame the larger universities for that. We think one of the problems is underfunding at the undergraduate levels. What works at those undergraduate levels is something that is extremely difficult to carry out with the larger classes, the lack of equipment, the laboratory problems, the outdated laboratories, the health problems one can encounter just be going into some of these facilities that were designed at a time when we were not aware of all these problems.

I think an increased focus on the undergraduate, and also I fully support the increased focus on the precollegiate education, is a way to help us through this era. But I do think we as a country tend to be a one-issue country. I am certainly no expert on how we can get people to maintain an interest after we have had a big event.

Mr. NAGLE. I thank you very much. I think I have gone over my time here. I thank the Chairman for his indulgence.

Mr. BOUCHER. The Chair thanks the gentleman and thanks this panel of excellent witnesses for their presentations this morning. What you have said and your responses to our questions have been extremely helpful to us, as we evaluate the National Science Foundation's fiscal year 1992 budget.

With the Chair's thanks, this panel is dismissed.

We now welcome our second panel of witnesses, Dr. Martha Green, the Secondary Science Specialists for the Florida Department of Education, Dr. Tony Heiting, the Science Consultant for the Iowa Department of Education, and Dr. Allan Hartman, Director of Research for the Massachusetts Department of Education, Office of Planning, Research and Evaluation.

Without objection, the prepared written statements of each of our panelists will be made a part of the record. We will be pleased to receive an oral summary of those statements from our panelists. The subcommittee has a five-minute rule with regard to oral statements, and we will ask the panelists if they could keep within that time limitation in terms of their opening statements. That obviously would provide more time for the subcommittee members to ask questions.

We welcome each of the panelists, and Dr. Green, we would be happy to begin with you.

STATEMENT OF DR. MARTHA M. GREEN, SECONDARY SCIENCE SPECIALIST, FLORIDA DEPARTMENT OF EDUCATION

Dr. GREEN. Thank you, Mr. Chairman. Thank you for allowing me the opportunity to testify about the National Science Foundation program, with which I am familiar.

I have a slightly different viewpoint than the gentlemen you have heard before in that I do deal strictly with the precollegiate science education, K-12, for the State of Florida Department of Education, specifically secondary science programs. I have been associated with lots of NSF grants in my 25-year career in science education, as a teacher and a science educator, as well as a bureaucrat in the Department of Education.

Some of those programs, as I indicated in my written testimony, have been very, very successful. Some have been fairly ephemeral. The ones that have been successful seem to be the ones that have a more comprehensive approach, curriculum projects, for example, that have associated with them teacher education factors.

Many of the programs for the students, the high school students and middle school students, have been extremely successful in the State of Florida. The Young Scholars program, we have had that program at several of our universities the past several years, has produced Westinghouse Finalists. We have had the participation of minorities in our comprehensive minority student centers, which is based at Florida State University and has satellite centers in the historically Black colleges throughout the State of Florida.

These programs have all encouraged young people to enter the universities and major in science. As a matter of fact, the Young Scholars and the older Summer Science Training programs indicate a 90 percent rate of students entering the universities with a declared interest in majoring in science or mathematics.

We have been asked to comment on the systemic initiatives program that is a new National Science Foundation program to bring large-scale changes in science education in the various states. As I mentioned in my written testimony, as we speak today, the State of Florida has a visiting team from the National Science Foundation to determine whether our application for a grant for that systemic initiative will be funded.

The strong points of the general systemic initiative program is that it goes beyond simple curriculum development. Many of the programs in the past have been rather spotty in that there have been just curriculum development in earth science, or middle school science. This systemic initiative will have as its end result a change in an entire system.

It also, instead of just developing a curriculum, addresses the barriers to the acceptance of those curriculum and encourages implementation of such curricula. It requires certain serious commitment by the participants in the systemic objectives, and as we all know, if one has commitments to a project, those projects are probably more likely to succeed.

In contrast with many of the NSF programs for K-12 students in the past, this goes beyond just looking at the gifted or the minorities. It looks at all the students and provides programs for all the students.

I would like to follow up on Dr. Gavin's point about big science and small science. Small scientists become big scientists. When you look at the first graders counting pumpkin seeds, you know that is a small scientist at work. What I would like to encourage is a project to strengthen the undergraduate science and math teacher education.

In particular, the science teachers will go through liberal arts schools or a large university and will take laboratory science courses, and they will have all kinds of very sophisticated experiences. They will go into the elementary and middle school and try to translate that experience into hands-on experiences for young children. Sometimes that does not translate without some help from the education college in the university.

The second point I would like to follow up on is the AAAS Science for All Americans and develop a set of national standards and assessment standards for science education from which we can develop a national assessment program to see just exactly how we are doing in science.

I think I have probably gone over my time limit. I am very pleased with the results of the National Science Foundation programs that I have been associated with over the last few years. I commend you to continue the efforts in the K-12 area.

Thank you.

[The prepared statement of Dr. Green follows:]

Testimony

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
MARCH 12, 1991

Martha M. Green
Secondary Science Specialist
Florida Department of Education

Honorable Sirs and Mesdames:

It is with great honor and pleasure that I respond to your request to testify for the purpose of reviewing the National Science Foundation activities for improving pre-college science education. I have been with the Department of Education in Florida as Secondary Science Specialist since January of 1984 and before that was a science teacher in several of Florida's secondary schools. In both capacities, I participated in many of the NSF initiatives for pre-college science education.

Historically, some of the early NSF projects are still bearing fruit. Many of the schools in Florida are using the **Biological Sciences Curriculum Study (BSCS)** text materials; **Introductory Physical Science (IPS)** is alive and well; and the many NSF-developed elementary school programs are still a resource through CD-ROM archiving and retrieval. In addition, many of the science educators in leadership positions throughout the state of Florida received their higher education through **NSF Summer and Academic Year Institutes**.

Programs for students have been successful in attracting young people into science, mathematics or engineering careers. Florida A&M University operates the NSF supported **"Comprehensive State Center for Minorities"** with branch centers throughout the state of Florida. These centers have motivated minority youth to enter careers in science and engineering. For many years, both The Florida State University in Tallahassee and the University of Florida in Gainesville have operated summer research programs (**Summer Science Training (SST) and Young Scholars)** for highly talented students. The majority of these students have gone on to university study in science or mathematics. Because of the rapidly increasing population of the state of Florida, more of these centers are needed, particularly in the most densely populated southern part of the state.

Teacher education grants including the **Honors Teacher Seminars** have been few but successful in promoting increased competence in science and mathematics teaching. Again, however, due to the burgeoning population of Florida, and the increased need for science and mathematics teachers because of our three credit requirement in mathematics and science for graduation, many more teacher education programs are needed.

The **Presidential Awards for Excellence in Science and Mathematics Teaching** has been a very successful program in our state. Despite the difficulties of conducting the search in a state that is large both geographically and in population, the pool of teachers that have been identified as outstanding by their peers have inspired other teachers. The grants to the schools of these outstanding teachers have often been used to provide inservice to the Awardees' colleagues, thus resulting in a multiplier effect for the NSF funds. In addition, Presidential Awardees from Florida serve on many state advisory committees and have infused their expertise into all areas of curriculum, assessment and inservice development. The addition of the Elementary component to the Presidential Awards program is an excellent way to focus on the often neglected essential of good science education: the elementary school teacher.

Last summer, I visited one of the state supported Summer Science, Mathematics and Computer Camps and watched middle school children investigating local environmental problems and producing a multimedia report using a new product supported under the NSF's Instructional Materials Development Projects. These children, in seven different sites near Ocala were using the **Science Vision** interactive media disks developed at Florida State University. As an experienced observer of classrooms and science activities, I was pleased to see the level of engagement of the students in problem solving and the high use of critical thinking skills as they used the program in the context of their own communities. This project is hailed by Florida technology educators as being the "next generation" in interactive media for classroom use.

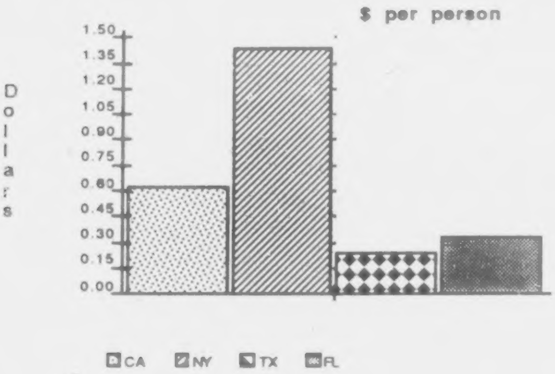
A new focus for NSF is embodied in **"Leading Mathematics into the 21st Century"**. This project helps mathematics educators to understand the basis for change in mathematics education, to assist in the development of networks to bring about change, and to create a more conducive atmosphere across the country for making changes in mathematics education. Given the development of national standards for mathematics education, this program should assist in providing the proper climate for their implementation. So often, wonderful ideas are developed, but the public relations strategies necessary for widespread implementation have not been fully used. NSF is to be commended for recognizing the need for and supporting this effort.

I have been involved since the beginning in the **Networks** project with **IBM and the Council of State Science Supervisors**. Because of this project, the state of Florida's science and mathematics specialists have been able to keep in daily touch with their colleagues throughout the United States and its territories. This has assisted us in keeping up-to-date on national projects in science and mathematics education, in participation in surveys requested by governmental and policy agencies, and in sharing successful practices in science and mathematics curricula. As a second phase of this project, Florida is operating an intrastate computer conferencing network, Florida People Sharing Information (FLOPSI), that has as its aim linking the science educators of the state so that similar sharing may be done within the state. Already several of our six regional Centers of Excellence for Science and Mathematics, the President of the Florida Association of Science Teachers, several members of the Florida Association of Science Supervisors, members of the Florida Marine Science Association, the Florida Association of Presidential Awardees and other individuals interested in science education are members of the network. The network "shadows" the national CCCS network and shares in national curriculum information.

There are several areas that my colleagues and I would like to see addressed by future NSF actions. First, there is a need for increased support of exemplary or innovative science and mathematics teacher education programs, particularly at the undergraduate level. Science and mathematics educators over and over point to the need for "hands-on" learning. Too often, new science and mathematics teachers graduate from the post-secondary institutions modelling their teaching in elementary and secondary schools on the lecture methods of their professors. Teacher preparation institutions need science and mathematics labs with **appropriate** equipment and supplies that would prepare student teachers to teach laboratory experiences to the nation's children.

Secondly, there is a need for science educators to follow the lead of the mathematics educators in developing a consensus national curriculum and evaluation standards for school science. The major study by the American Association for the Advancement of Science, Science For All Americans, has developed a consensus statement of what the well-educated American should know in science. Now it is time for the science educators to determine the curriculum and evaluation standards to carry out the challenge. This would assist in the development of better textbooks and national assessment instruments and would assist our highly mobile population to move from state to state and not lose continuity in its education.

Third, the funding that affects all of America's youth should be distributed more proportionately as to population patterns. As is shown in the graph below, the FY 1989 funding from the Directorate of Science and Engineering showed significant differences in the dollars per person in the four largest states, CA, NY, TX and FL, with the southern states receiving significantly less funding than California or New York.* For programs that impact all youth, not just university researchers, equity in funding should be a primary concern. It seems appropriate to suggest that encouragement of science education in the emerging South could be greatly facilitated by a more proportionate share of these tax-generated public funds, and children in the United States would be better served by increased encouragement and support in the areas where the population is moving.



Your witnesses have been asked to comment on the **Systemic Change Initiatives**. In view of the fact that Florida has a proposal that is pending funding, and that during the day of this testimony, a NSF visiting team is interviewing the Florida team in Tallahassee, I feel that it is

*From Oct., 1989 population figures and SEE Directory of Awards, FY '89 inappropriate for me to talk about the specifics of the proposal. However, it is an interesting concept. Change throughout an entire system is something that Legislatures have tried to effect in many states. It will be interesting to compare the effectiveness of grants vs. legislative initiatives in the states whose grants are funded.

In sum, NSF funding has had positive effects on the pre-college education in science and mathematics in the State of Florida and in the nation. I encourage the continuance of these good efforts and support the increase in funding for the National Science Foundation's Directorate for Science and Engineering Education.

Biographical Sketch

Martha M. Green

Born in Bradford, PA, Martha Green received her bachelor's degree in science from the University of Rochester and the master's and doctorate in education from the University of Florida. She is the widow of the late Cdr. W.E. Green, USNR, and the mother of three: the youngest of whom is a B-52 navigator soon to return home from duty in the Persian Gulf.

Dr. Green taught in the public schools in Jacksonville and Gainesville, FL, teaching chemistry, earth science, biology, astronomy and computer programming in BASIC. She also was Visiting Associate Professor at the University of Florida, teaching science curriculum and methods and instructional microcomputing. She was awarded the Florida Section, American Chemical Society's "Outstanding Florida Chemistry Teacher Award", and the Florida Association of Science Teacher's "Outstanding Secondary Science Teacher". She was state runner-up for the first Presidential Award for Excellence in Science Teaching.

She has been the State of Florida's Secondary Science Specialist in the Division of Public Schools for seven years. She serves on the Board of Directors of the Council of State Science Supervisors. She presently resides beside a pond in Tallahassee, FL and grows vegetables in her back yard.

Mr. BOUCHER. Thank you, Dr. Green.

Dr. Heiting, we will be pleased to hear from you.

STATEMENT OF DR. W. TONY HEITING, SCIENCE CONSULTANT, IOWA DEPARTMENT OR EDUCATION

Dr. HEITING. I am pleased to have this opportunity to speak before the subcommittee on the important issue of precollege science education and the role the NSF plays in strengthening science programs throughout the country. I work with precollege science education as well as at the collegiate level, so I have an opportunity to see a variety of needs, at least in the State of Iowa.

Iowa is recognized as a leader in education. Iowa students continue to earn high marks in college entrance exams and standardized tests. Our State's high school graduation rate is among the Nation's best. We are very proud of our education system, but we are not too proud to say it can be better.

Iowa shares many of the same problems in science education as do other states. These include inadequate student achievement in science and mathematics, low enrollments in math and science courses, particularly women and minorities, as Dr. Hooper mentioned before, inadequate preparation of math and science teachers, lack of student interest in science and math, and inadequate instructional facilities and equipment for teaching science.

When you add to this list the national concerns of scientific literacy among our American public, the shortages of individuals to fill the critical scientific and technical jobs that Representative Nagle alluded to, and U.S. students being ranked near the bottom in international studies and students achievements in math and science, you might say that science education in this country is in a state of turmoil.

Major problems in science education I feel have been identified. The causes of these problems are fairly well understood. What is not well understood is how to resolve the problems. The problems I have been mentioning in science education are not endemic to Iowa, but they transcend across the country. That makes this a national problem in science education. The Federal Government must leverage and make the most effective use of its resources and to improve mathematics and science education.

It is my opinion that it would be prudent to channel significantly more money into precollege science education programs to improve the quality of instruction, curriculum and retain student interest. Otherwise, we will not have enough students in the sciences at the undergraduate levels and graduate levels to work with and fill the increasing scientific and technological positions being created in this country.

Less than six percent of our students in this country are entering colleges in the sciences, and many change their majors before they graduate. The question is, are we turning off the other 94 percent from the sciences? It is my opinion that in too many cases the answer is yes, for the reasons I mentioned before, which include poor teacher preparation, inadequate instruction and facilities, lack of proper curriculum, and necessary organization or reforms in the schools that need to be made to teach science.

These are just some reasons for why we need increasing support at the precollege science level. This brings me to the role of the National Science Foundation in strengthening math and science education in this country. The NSF has been instrumental in advancing scientific research and scientific education activities in many fields of science. Iowa schools have been aggressive in pursuing funding from the NSF to improve science and math education.

In the past five years, 113 science and math projects have been funded in Iowa, the majority of the money coming from NSF. These projects include curriculum development, problem solving, teleconferencing, teacher enhancement, and in-service workshops for teachers and students.

In general, these NSF projects have proven to be very effective for the educators that were targeted. They resulted in curriculum and instructional models that have advanced science education in many schools in the State. While these projects have been positive in accomplishing their stated goals and objectives, they have for the most part been fragmented efforts. These projects need to fit within the parameters of statewide goals in science education if they are to be totally effective and have value.

I commend Congress, the Administration and NSF for establishing the new Statewide Systemic Initiative program for improving science and math education. This partnership between the Federal government and the states is exactly what is needed in restructuring precollege science education and looking beyond to those changes that need to be made in teacher preparation programs and certification requirements and standards for teaching science.

The response to this first year of systemic initiative should be a strong indication of the state's interest and concern in improving science education. Iowa was one of the 30 states that submitted a comprehensive proposal for systemic change (see appendix for proposal). Unfortunately, like my colleagues on both sides of me, we were not one of those selected for funding. While we were disappointed, we are going to continue to submit a proposal for the next round of funding, which we understanding will take place through NSF. We look forward to this opportunity.

Three of the six national education goals developed following the 1989 Education Summit are directly related to math and science education. That again emphasizes that we have a national problem. If we are going to come close to meeting these goals by the year 2000 in mathematics and science education, major initiatives need to be implemented immediately. This will require the continued and increasing budget support from Federal and state governments.

The National Science Foundation should provide the leadership and resources for state reforms that are needed in these areas.

Thank you.

[The prepared statement of Dr. Heiting follows:]

TESTIMONY

BEFORE THE U.S. HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON SCIENCE
ON THE NATIONAL SCIENCE FOUNDATION AUTHORIZATION

MARCH 12, 1991

DR. W. TONY HEITING
SCIENCE CONSULTANT
IOWA DEPARTMENT OF EDUCATION
DES MOINES, IA 50319

I am pleased to have the opportunity to speak before the subcommittee on science on the important issue of precollege science education and the role of NSF programs in strengthening K-12 science and math instruction in Iowa.

Iowa is recognized as a leader in education. Iowa students continue to earn high marks on college entrance exams and standardized tests. Our state's high school graduation rate is among the nation's best. We are proud of our education system, but not too proud to say it can be better.

Iowa shares many of the same problems in science education as do other states. These include inadequate student achievement in math and science; low enrollments in math and science courses, particularly women and minorities; inadequate preparation of our math and science teachers; lack of student interest in science and math, and inadequate instructional facilities and equipment for teaching science. When you add to this list the national concerns of low levels of scientific literacy among the American public, the present and projected shortage of qualified individuals to fill critical scientific and technical jobs, and U.S. students being ranked near the bottom in international studies on students' knowledge of science and mathematics - you might say that science education is in a state of turmoil!

The major problems in science education have been identified and the causes of these problems are fairly well understood. What is not well understood is how to resolve the problems.

The problems that have been mentioned in science education are not endemic to Iowa, but transcend across the country. So what we have is a national problem in science education. Approximately 6% of the total spending for elementary and secondary education comes from federal sources. (By the year 2000, Report of the Federal Coordinating Council for Science, Engineering, and Technology on Education and Human Resources, 1991.) The remainder is supplied through state and local governments. Science education is a national problem and the federal government must leverage and make the most effective use if its resources to improve mathematics and science education. It is my opinion that it would be prudent to channel significantly more money into precollege science education programs to improve the quality of instruction, curriculum, and retain student interest. Otherwise, we will not have enough students in sciences at the undergraduate and graduate levels to work with and fill the increasing scientific and technological positions that are being created in the country. Only 6% of the students in our country are entering college in the sciences and many change majors before they graduate. Are we turning off the other 94% from the sciences? It is my opinion that in too many cases the answer is YES for the reasons I mentioned before, which include poor teacher preparation, inadequate instruction and facilities, lack of proper curriculum, necessary organizational reforms in the schools for teaching science (i.e. for field trips, labs), and lack of student support, incentives and opportunities. These are "just" reasons for why we need increasing support for precollege science education at the federal level.

This brings me to the role of the National Science Foundation (NSF) in strengthening math and science education in this country. The NSF has been instrumental in advancing scientific research and science education activities in all fields of science. Iowa schools have been aggressive in pursuing funding from the NSF to improve science and mathematics education. In the past five years, 113 science and math education projects have been funded in Iowa, the majority of money coming from the NSF. These projects have included curriculum development, problem solving, teleconferencing, teacher enhancement and inservice workshops for teachers and students. In general, these NSF funded projects have proven to be very effective for the educators that were targeted. They have resulted in curriculum and instructional models that have advanced science education in many schools in the state.

While these projects have been positive in accomplishing the stated goals and objectives, they have for the most part been fragmented efforts These projects need to fit within the parameters of statewide goals to improve science education if they are to be totally effective and of value. I commend Congress, the Administration and the NSF for establishing the new Statewide Systemic Initiative program for improving science and mathematics education in the states. This partnership between the federal government and the states is exactly what is needed in restructuring precollege science education and looking beyond to those changes that need to be made with teacher education programs, certification requirements and standards for teaching science. The response to this first year systemic initiative program should be a strong indication of the states' interest and concern in improving science education. Iowa was one of the 30 states that submitted a comprehensive proposal for systemic changes in math and science education (copy of the proposal included with this written testimony). Unfortunately, we were not selected to be funded in the first round of this program. While we were disappointed, we are not discouraged because we understand we can submit a proposal to the NSF for the next round of funding. We look forward to this opportunity.

Three of the six National Education Goals developed following the 1989 Education Summit are directly related to mathematics and science education, which again emphasize that we have a national problem.

GOAL 3 - By the year 2000, American students will leave grades four, eight, and twelve having demonstrated competency in challenging subject matter including English, mathematics, science, history and geography; and every school in America will ensure that all students learn to use their minds well, so they may be prepared for responsible citizenship, further learning, and productive employment in our modern economy.

GOAL 4 - By the year 2000, U.S. students will be the first in the world in science and mathematics achievement.

GOAL 5 - By the year 2000, every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship.

If we are going to come close to meeting these goals in mathematics and science education, major initiatives need to be implemented immediately. This will require continued and increasing budget support from the federal and state governments. The National Science Foundation should provide the leadership and resources for the state-wide reforms that are needed in science and mathematics education.

BIOGRAPHICAL SKETCH

DR. W. TONY HEITING

DR. HEITING IS THE STATE SCIENCE CONSULTANT FOR THE IOWA DEPARTMENT OF EDUCATION. HE WORKS WITH ALL IOWA SCHOOLS AND TEACHERS (K-16) IN EFFORTS TO IMPROVE SCIENCE EDUCATION IN THE STATE.

DR. HEITING RECEIVED HIS PH.D IN SCIENCE EDUCATION FROM THE UNIVERSITY OF IOWA. HE HAS 10 YEARS OF TEACHING EXPERIENCE AT THE SECONDARY AND COLLEGE LEVELS. HE WAS THE PRINCIPLE AUTHOR OF IOWA'S PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION FOR STATEWIDE SYSTEMIC IMPROVEMENTS IN MATHEMATICS AND SCIENCE.

Dr. W. Tony Heiting
State Science Consultant
Iowa Department of Education
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(515-281-3249)

Mr. **Boucher**. Thank you, Dr. Heiting.

Dr. Hartman, we will be pleased to hear from you.

STATEMENT OF DR. ALLAN HARTMAN, DIRECTOR OF RESEARCH, MASSACHUSETTS DEPARTMENT OF EDUCATION, OFFICE OF PLANNING, RESEARCH AND EVALUATION

Dr. **Hartman**. Thank you, Mr. Chairman. I am pleased to be here on behalf of Commissioner Harold Reynolds, of Massachusetts, to endorse the fiscal year 1992 NSF budget request. We are particularly pleased to support the increase proposed for the precollege activities emphasizing improved teacher preparation.

As you know, due to one of those quirks of scheduling Commissioner Reynolds could not be here today. At this very moment he is discussing with the NSF visiting team our response to the Statewide Systemic Initiatives program, as is the case in Florida. This program seeks to foster state collaborative efforts in improving adopting of more effective curricula, better instructional materials, more relevant assessment procedures and better teacher preparatory and in-service programs, all to have the ultimate effect of improving student achievement in math and science.

This program is of particular interest to us. It enables us to mount a very comprehensive approach to improving the instructional capacity of our K-12 public school practitioners, through coordinating a wide variety of support services to assist in the effort, and by doing so bridge the gap between those in need, meaning the schools, and those with the materials, experience and expertise to provide such services.

We are extremely gratified that NSF will be recognizing the State as an important agent in facilitating, integrating and focusing resources on public school improvement. You are well aware, I am sure you have had a multitude of testimony, about the need to strengthen math and science instruction in the Nation's schools. The data from our own statewide assessment, which parallels those of NAEP, shows that less than eight percent of our students in our state can perform in either math or science at the highest level of proficiency. We have identified in many ways like NAEP has.

Second, the vast majority of our students experience extreme difficulty in performing satisfactorily on math and science tasks requiring application skills, critical thinking, and problem solving. We get into these tasks and we move away from the simple multiple choice tests.

While there are many factors that are related and linked and associated with this disappointing performance on the part of our Nation's youth in math and science, I would like to cite a few other factors that appear to have a rather relevant association when it comes to the State initiatives program, in the area of school and student attitudes and school practices. In our assessment, and from the data we have, we have noticed a decrease between the 8th grade and the 12th grade in students who find math and science useful in understanding the world around them and getting along in everyday life. We would want the reverse to happen.

Second, at grades 8 and 12 more than half of our students — and this is in Massachusetts, but in many ways it is paralleled in

NAEP data—more than half of our students spend less than one hour a week on science homework. There is a very significant relationship between homework and science and performance. We have all this data showing this type of relationship.

Over 50 percent of our 8th and 12th grade students, when asked, believe that math and science mainly involves memorization. It is just the opposite of what you would want to happen from meaningful types of science programs. More relevant than looking at the state initiative programs as they impact on teaching instruction, in our assessment we got a lot of information from the schools and from teachers. More than 40 percent of our 8th and 12th grade teachers report that their science equipment is in poor to fair condition. This gets at the issue of materials—people just don't want to give money for things. But that does leverage other types of activities.

Only 38 percent of our middle schools require four or more hours per week of instruction in science and math. More than half of our elementary schools in Massachusetts have a budget of less than $250 a year for science equipment. Some 57 percent, 57 percent, of our 8th grade science teachers, have a degree in some area of science, while only 46 percent of 8th grade math teachers have a degree in mathematics. Almost 50 percent of our 4th grade teachers have taken only one course in math and one course in science.

Finally, while 65 to 75 percent of 8th grade math teachers place considerable emphasis on such things as fractions and decimals and percentages, less than eight percent give similar emphasis to geometry, probability and statistics.

There is obviously a causal relationship between these facts. If you are not well educated in science and math, you tend not to emphasize the higher order of things in math and science, and you tend not to give as much time in your programs to math and science. These are all linked. These weaknesses and shortcomings in the teaching of math and science are the basis of the proposal we have submitted to NSF in terms of a state initiative program. More specifically, NSF has identified various components needed to bring about systemic change.

We are responding to five, the five have to do with organizational structure and decision making, recoupment and preparation of teachers, retention and continuing professional development of teachers, curriculum content and learning goals, and assessment of student achievements. I am probably the only one who does not come from a science background on the panel this morning, so I could probably address the area of more adequate assessment of student learning.

Time does not allow me to go into more detail. Let me close by saying that with NSF support, we shall be building over the next five years in Massachusetts a variety of technical assistance and telecommunications networks, demonstration sites and programs, and with business and industry and university partnerships, focus on raising the level of science and mathematics instruction and with this, student achievement.

Thank you.

Mr. BOUCHER. Thank you, Dr. Hartman, and our thanks to all the witnesses for their very helpful presentation this morning in terms of the effect of NSF-sponsored programs in secondary education.

In order to help us better analyze the effectiveness of those programs, I wonder if each of our panelists today would give us an indication of which of the NSF-sponsored programs are most effective in terms of advancing secondary education goals in their states?

Dr. Green, we will begin with you.

Dr. GREEN. Thank you, Mr. Chairman. I think if we look historically at the programs that have been most effective in advancing secondary education in the states, they are those programs that are directly involved with teacher education, particularly in-service teacher education, not the new teachers, but the teachers who have been in the schools for some time. These programs are associated with changes in curriculum for the teachers during their in-service education to learn about the new curricula and learn how to do hands-on experiments and how to actually carry out the curricula in the classroom.

Mr. BOUCHER. Do you think current funding levels for that program are sufficient?

Dr. GREEN. Of course not. I think we could do a whole lot more in that area. Compared to the Sputnik era, we had a lot of academic institutes, a lot of summer institutes. At this point in time, it is not enough, particularly in a State like Florida that is growing so fast and needs more assistance in preparing our need for teachers.

Mr. BOUCHER. So you would argue that to the extent we apply greater resources towards secondary education programs, we should target that particular area?

Dr. GREEN. Teacher education I think is crucial.

Mr. BOUCHER. Okay. Dr. Heiting?

Dr. HEITING. I would agree with Dr. Green. Teacher enhancement is a main concern that most of the states have. I would, however, emphasize that the concerns should be at the elementary teaching level, and I feel this way because if this does not happen, we are not going to have students at the secondary and collegiate levels to deal with in entering the sciences.

The other program, as I mentioned in my remarks that I am very supportive of, is the systemic effort NSF has started in the past year. This sort of coordination forces the states to coordinate the science and math education activities, which has been long overdue.

Mr. BOUCHER. Dr. Hartman?

Dr. HARTMAN. I would agree with Dr. Heiting. I think the emphasis should definitely be at the elementary school level, especially given the facts that I have mentioned, that the average 4th grade teacher has taken one course in their entire professional education in math, and maybe one course in science, and that is all they are running with. If you look at reading, math, science and social studies, the amount of time in the 4th grade classroom, science is at the bottom in terms of time.

The nature of a program with teachers, we have found from experience with NSF grants, should be away from that which is textbook bound, it should be hands-on, experiential, it should involve open inquiry, and it should be collaborative. You teach the way you have looked and taught. Those programs have to be taught in that way, if it is to impact the way we want teachers to teach.

Mr. BOUCHER. Let me ask you now for the other side of the coin. Are there programs sponsored by NSF that have been of minimal effectiveness, that you would put at the bottom of the scale? Dr. Green?

Dr. GREEN. That's a very difficult question. I can think of one program that dealt with the development of some videotapes that was funded and never really got off the ground. The tapes were developed but there was no provision in the NSF proposal or the funding of the grant to disseminate those tapes anywhere but in the library of the institution that developed it.

I think whenever there is curricular development, there should be some way to get it out into the schools, have teachers and administrators aware of the curriculum development and make sure any materials development is accompanied by some kind of dissemination strategies and education.

Mr. BOUCHER. Dr. Heiting?

Dr. HEITING. I am not familiar with all the NSF programs, but I cannot think of any in the precollege science education and math education that have not been valuable. The only concern I would have is that there needs to be perhaps more of an assessment of the effectiveness of these programs required by NSF.

Mr. BOUCHER. How would you recommend we assess their effectiveness? What kind of mechanism should we use? We have these hearings, and that's part of our purpose, but beyond this, what should we be doing?

Dr. HEITING. I think probably what needs to be done is that the evaluation of the programs needs to be built into the original request for the proposal. Right now, in many cases, that is lacking. It is characteristic of education in general, unfortunately, but perhaps more so in the sciences and math.

Mr. BOUCHER. Interesting thought. Dr. Hartman?

Dr. HARTMAN. Again, I am in agreement with Dr. Heiting. I do not have any first-hand familiarity with any NSF programs, that has not been my area. I do know of programs. I don't know if they were NSF-sponsored, that have been ineffective.

I consider programs that are given in leftover time of a teacher for an hour after school and that's it—a quick fix, a demonstration, someone stands up in front and presents science as magic—basically that's ineffective, or large conferences in which big name speakers are engaged. Those types of efforts, no matter who sponsors them, take time, don't change much. They are of short duration, and people don't have what I mentioned before, hands-on experience, education involving open inquiry.

I do agree with Dr. Heiting that you have to have evaluation built into these programs. Unless you have that, you are going to be dependent upon anecdotal evidence about what does or does not happen. You have to look at the impact on teacher behavior in the classroom.

My experience with NSF programs goes back into the 1960s, especially in terms of AAAS science programs, science process approach, which was a big thing in the middle 1960s. I saw training that was very exciting, in terms of a process approach to science in the 1960s.

But when you went into the classroom and observed a teacher who was used to running a classroom himself or herself, and dominating and directing the classroom, trying to fit into the mold of an inquiry approach where there was not a right answer, you found all sorts of difficulties with many teachers. That's the only place you can find out if your programs have made a difference.

Mr. BOUCHER. Thank you very much for your comments. I have only one other question, then I will yield to my colleagues.

We are always interested in new directions that the NSF might take, new initiatives that it might pursue. I wonder if you could give us any examples that come to mind based on your experience of state-initiated education programs that might serve as models for the NSF, for national application. Do you have any items that come to mind you would like to share with us? Any volunteers?

Dr. HARTMAN. I come from, as I mention, the area of testing, research and evaluation. We have involved teachers in the design and development of math and science tasks which involve students in doing things in science and mathematics in a collaborative approach. The kids do things and they are rated by observers. We have had to train teachers to observe kids doing science.

The tasks could be as mundane as putting a big bowl of popcorn in front of kids and asking them to estimate, giving them some weights and balances and cups and seeing the efficiency they apply to the task and how they plan to carry out this task of estimating popcorn.

What is fascinating sometimes in looking at this thing, just as a side note, is that kids who get As and Bs in math paperwork don't necessarily perform very well when it comes to an application thing, a real live task. One thing we do find out, though, when we involve teachers in doing more meaningful assessments of math and science learning is that it backs up into instruction. It affects the way they go back into the classroom and the way they look at what meaningful science instruction is. It is sort of an enlightened assessment affecting instructional practices. That's the only thing I can bring from our experience.

Mr. BOUCHER. Thank you, that's very helpful.

Dr. Green?

Dr. GREEN. In the State of Florida for the past four or five years, we have had a very successful summer camp program, where private non-profit places like museums, as well as school districts, as well as universities, have applied to run summer camps for science, mathematics and computer education. These summer camps range from those for gifted seniors all the way to one or two day experiences for first grade students, held at the seashore with marine biologists, teaching these youngsters about the critters in the ocean.

The thing we have found was what we expected, that there would be a lot of learning by the students and a lot of enrichment that the schools would pass back to us as being positive in engendering interest in science. In addition, we have found the teachers who have been involved with these summer camp programs have become actual researchers in science education and have developed their own curricula.

It is just absolutely fascinating to see some of these people, elementary school teachers, for example, who before were not interested in science, were scared of science, didn't think they could teach science, actually coming out and doing a summer camp and finding out that they like science. They like to teach science. My kids like science. It's easy.

Mr. **Boucher**. Thank you. Dr. Heiting?

Dr. **Heiting**. One thing that comes to mind is a teleconferencing network program that was initiated in the State and later funded by NSF which allows science supervisors around the state as well as science teachers to communicate immediately electronically as to what they are doing in the areas of science and sharing science information as well as getting access to information at the national level. This has improved the communication in science education dramatically. We hope it continues to grow, as it looks like it is going to.

Mr. **Boucher**. Thank you very much for those suggestions. If you have, on reflection, additional examples you would like to offer to us as directions the NSF might take based on your State's experiences, we would be very happy to receive that from you, and you can communicate either by telephone or letter to us those examples.

The gentleman from Iowa is recognized.

Mr. **Nagle**. Mr. Chairman, I would first like to note for the record of this hearing that balance has been restored. Dr. Heiting is a graduate, has his Ph.D. from the University of Iowa. The record should reflect that and it should be underlined. I did not want this panel to go the entire day hearing only from Big 8 school when in fact we have a Big 10 school present.

But I would like to—and I appreciate your coming here from Iowa, Dr. Heiting—I would like to ask the panel the Congress and the Chairman's question. In meeting with my own — not my own— but the math and science instructors of the University of Northern Iowa earlier this month, or late last month, they indicated to me that one of their frustrations was the cancelling of programs that seemed to have merit, and seemed to be pursuing.

They cited one they were in for three years, which was to teach teachers to teach math and science. They were to bring in 50 in the summer and instruct them, and those 50 were then to go back to their areas and locales and pass that teaching back again to another 50.

The program ran three years, and seemed to be well graded, well received and well marked. Then it was cancelled because NSF started a new initiative in a different direction. I am curious to know whether or not—not only do we need the evaluation, I like that concept—but I sometimes think the problem might be even here in the institution. I would love to have the Dave Nagle Memorial New Initiatives in Mathematics Appropriation, so I could take it home, but to do that I would have to cancel different programs.

Is there a way we can get at the problem of not only weeding out bad programs, but perpetuating good programs? We seem to start and stop with new initiatives. We have so many new initiatives every year we do this. To me it's a maze just trying to keep up with what they are. I am curious as to the panel's observations on that, not only cancelling bad programs but maintaining good programs.

Dr. **Green**. I think you will find that the good programs perpetuate themselves or are perpetuated by other agencies or funding sources. For example, some of the very good curriculum development projects of the early 1960s, specifically the BSCS projects and the ESCP projects, were picked up and developed further by various publishing companies in the private sector.

We have had some projects from a long time ago that were started by NSF and have since been picked up by private sector and some by public sector, State funding. The ones that were not very good seem to have just gone away. You raise a good point—how do you know which ones are good and which ones should not be funded. I think building on Dr. Heiting's suggestion, that there should be assessment programs built in.

But rest assured that if something is good and NSF stops funding it, somebody else will pick it up.

Mr. **Nagle**. I do agree, though—I understand maybe the built-in evaluation process would be helpful. I do agree with Dr. Heiting's statement that science education is a national problem. The Federal Government's leverage can make the most effective use of its resources to improve mathematics and science education.

I frankly don't find it too comforting that good programs are dependent on the private sector picking them up and perpetuating them. I think that's what we have done for 10 years, assume the free market enterprise system is going to solve all the problems in this country. Obviously, one problem it can't solve, based on our decade of experience, is science and math education. That theory has not been translated. Adam Smith was wrong. That was one of his theories.

But I appreciate your answer, and I would just the other two panel members to comment quickly on that generic question.

Dr. **Heiting**. I am familiar with the project you mentioned at the University of Northern Iowa, it was an excellent program.

I think, Congressman Nagle, one way to weed out NSF programs is to make sure the State develops overall goals and objectives in science education. If a particular project that is ongoing or that is being proposed does not fit in with those objectives, then perhaps it should be looked at in a different sphere. As I mentioned in my remarks, while Iowa has done tremendous things in science education, it has been too fragmented, and it has targeted individuals, but has not done anything for Iowa, Iowa State or any other regional institutions.

This is one of the major problems. We are beginning to see a lot more interest in building partnerships with business and industry in the State of Iowa because they realize that in another five or ten years, they are not going to have qualified people to fill available positions. So we are looking at partnership in that area, also.

Dr. **Hartman**. I am the non-scientist here, so my response may be irrelevant. Let that be noted for the record, also.

Mr. **Nagle**. In that case, you and I can communicate with one another, because I am not, either.

Dr. **Hartman**. I think Dr. Langenberg mentioned in his presentation or response to that question, the funding for science and math has been sporadic over the decades of my professional life. I mentioned the 1960s. There were AAAS science programs that came in and faded away. I don't know how many iterations, interest and effort, and discontinuance of programs in States.

I have worked in four different States and I have seen programs go away and vanish, project this and project that. That was wonderful in its heyday and had all sorts of great effects. Then you go back to that school, and it doesn't exist any more. It is either because of lack of funding, the people have moved out, the pioneers are gone on to other things.

It is very easy to get an impact on the first 10 percent of schools on anything, over a relatively short period of time. They can do things. In our State, I could mention the districts that always—the doctors, for instance. They take it on. They do a great job. They hold the workshops and say "Look, see what we have done."

It takes continued funding for an extended period of time to go beyond that 10 or 15 percent, to impact on your cities, in rural areas where teachers are not well trained, and to stay with it for a sufficient amount of time so it will impact. Usually it never gets that far, because as you said, national programs are into something else. If they shoot an archaeologists up in a satellite, it will be archeology.

Mr. NAGLE. I don't mean to cite you and I as a specific exception, except if you sit on this side of the panel you learn that if you have a problem at one institution, it probably is occurring in others. I don't know that I know the answer to the problem, either, but we do have a propensity up here to start and stop. I think we are probably as much to blame because we want to tinker with the stuff and create our own programs and initiatives.

But I found your testimony enlightening and I appreciate your coming out here today to testify. I appreciate it.

I obviously stayed through the entire panel because I have an interest in this. I have purposely tried to take the time this year, more than ever before, to focus on this, because I think it is the future, and I think the strength of this country may very well come from results of the work that people like you do.

So I thank you for being here.

Mr. BOUCHER. The Chair thanks the gentleman and again extends thanks to this panel of witnesses, all of whom have traveled a great distance in order to share their ideas with us today. I want to assure you that your recommendations and suggestions are important in this ongoing process.

So with the Chair's thanks, this panel is dismissed, and this hearing is adjourned.

[Whereupon, at 12:10 p.m., the subcommittee adjourned, to reconvene at the call of the Chair.]

FISCAL YEAR 1992 AND 1993 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

WEDNESDAY MARCH 13, 1991

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE,
Washington, D.C.

The subcommittee met, pursuant to recess, at 9:30 a.m. in room 2318, Rayburn House Office Building, Hon. Rick Boucher [chairman of the subcommittee] presiding.

Mr. BOUCHER. This subcommittee will come to order.

Today this subcommittee completes its hearings on the National Science Foundation's budget request for fiscal year 1992. During the first of our hearings, we received testimony from the Acting Director of the National Science Foundation and from the Chairman of the National Science Board. Yesterday we examined the proposed budget as a whole, and reviewed some of the Foundation's educational programs at the precollege level.

Today the subcommittee continues its examination of specific programs by focusing on the new NSF initiatives and research instrumentation, the proposed Laser Interferometer Gravitational-Wave Observatory, otherwise known as LIGO, and finally the new materials science initiative. Attention will also be given to the Administration's recommendation of zero funding for the research facilities construction program.

In 1988, responding to a well documented and widespread need for funds to upgrade outmoded research facilities, this committee authorized the Academic Research Facilities Modernization program at NSF. Funds for this activity were appropriated for the first time in fiscally year 1990 at the level of $20 million and were continued at that level in the fiscal year 1991 appropriation process. We noted with surprise that the Foundation requested no funds this year for facilities modernization. The subcommittee is not aware that either university needs or university access to alternative sources of funds for facilities has changed.

At the same time, however, we understand and support the rationale for the scientific instrumentation initiative, which is proposed by the NSF for fiscal year 1992. This fund would facilitate the purchase of scientific instruments that are too expensive to be acquired through normal research grants. Our first panel today will review both facility and instrumentation needs in academic institutions and will comment on the value of NSF programs designed to strengthen the research infrastructure.

This year the Foundation is requesting $23 million to begin construction of the Laser Interferometer Gravitation-Wave Observatory, known as LIGO. NSF proposes to build two identical, widely separated gravitational wave detectors at a total estimated cost of $211 million over a period of five years. Our second panel will address the scientific merit, feasibility and timeliness of this major undertaking.

Finally this morning, our third panel will focus on the proposed $84 million NSF materials synthesis and processing initiative. Future development of the critical technologies necessary to the Nation's continued economic competitiveness requires a strengthening of the fundamental scientific and engineering capabilities that will lead to the next generation of materials and processing methods. Today, among other inquiries, we will explore how the NSF initiative relates to the recent findings of the National Academy of Sciences study on needs and opportunities in materials science and engineering research.

Momentarily, we will welcome our first panel of witnesses. Before doing that, I would like to recognize the ranking Republican member of this subcommittee, the gentleman from California, Mr. Packard.

[The prepared opening statement of Mr. Boucher follows:]

OPENING STATEMENT
OF
THE HONORABLE RICK BOUCHER (D-VA)
CHAIRMAN, SUBCOMMITTEE ON SCIENCE
ON
THE NATIONAL SCIENCE FOUNDATION AUTHORIZATION HEARING

March 13, 1991

Today we complete our hearings on the National Science Foundation's budget request for fiscal year 1992. During our first hearing, we heard from the Acting Director of Foundation and the Chairman of the National Science Board. Yesterday we examined the proposed budget as a whole, and reviewed some of the Foundation's educational programs at the pre-college level.

Today the Subcommittee will continue its examination of specific initiatives in the budget proposal by taking a closer look at NSF programs to address research facilities and instrumentation needs at universities, proposed funding for the Laser Interferometer Gravitational Wave

Observatory (LIGO), and finally the new materials science initiative.

In 1988, responding to a well documented and widespread need for funds to upgrade outmoded academic research facilities, this Committee authorized the Academic Research Facilities Modernization program at NSF. Funds for this activity were appropriated for the first time in FY 1990 at $20 million and were continued at that level in the FY 1991 appropriation. We noted with surprise that the Foundation requested no funds this year for Facilities Modernization, although the Subcommittee is not aware that either university needs or university access to alternative sources of funds for facilities has changed.

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Finally, our third panel will review the adequacy of the proposed $84 million NSF materials synthesis and processing initiative. Future development of the critical technologies so necessary to this country's continued economic competitiveness depends directly upon strengthening the fundamental scientific and engineering capabilities that will lead to the next generation of materials and processing methods. Today, we will explore how the NSF initiative relates to the recent findings of the National Academy of Sciences study on needs and opportunities in materials science and engineering research.

We welcome all of our distinguished witnesses and look forward to your testimony.

Mr. **Packard**. Thank you, Mr. Chairman. As we begin our second day of hearings on the Administration's proposed Fiscal Year 1992 budget for the National Science Foundation, I would like to welcome all the witnesses that will be testifying before us today. I am particularly pleased to welcome Dr. Albert Johnson, the Vice President for Academic Affairs at San Diego State University, and previous to that, for seven or eight years, he served as the Dean of the College for Science. We are particularly pleased to welcome him. I am anyway, and thank you for taking time out of your schedule to be with us.

We look forward to your testimony, all of you. Yesterday we received a broad overview of how the priorities in the NSF budget will affect the academic community, with special emphasis on the precollege education. Today we turn our focus to more specific elements of the budget. These areas include: one, the elimination of funding for the facility modernization program; two, the initiation of a $50 million program for instrumentation; three, the inclusion of LIGO, a new program to detect gravitational waves; and four, the development of a new research program for materials synthesis and processing.

I look forward to hearing about the feasibility and timeliness of some of these initiatives. I am very anxious to hear how the programs will impact the educational community. Again, we look forward to hearing your testimony, ladies and gentlemen.

We are setting a precedent here on the Hill, the Chairman of this subcommittee, of starting these hearings on time, or as nearly on time as we can. Our colleagues sometimes have not gotten used to that yet. We think they will come in before your testimony is concluded, at least, and we hope they will be able to hear your testimony.

Again, thank you, Mr. Chairman, for calling this hearing.

Mr. **Boucher**. The Chair thanks the gentleman and recognizes the gentleman from Arkansas, Mr. Thornton.

Mr. **Thornton**. Thank you, Mr. Chairman. I have no prepared statement. I am looking forward to the testimony, which I have had a chance to briefly review.

I also want to congratulate you for starting the hearings on time. I would have been here on time but for a very slight delay visiting with a constituent in the hallway.

Mr. **Boucher**. Well, for practical purposes, the gentleman is here on time, and we will try to make that a tradition in this subcommittee, of starting at the appointed hour.

The Chair recognizes the gentleman from Indiana, Mr. Roemer.

Mr. **Roemer**. Thank you, Mr. Chairman. I am obviously late.

[Laughter.]

Mr. **Roemer**. I do have the excuse, though, that I was at another committee meeting. It seems like they schedule all these at the same time, Mr. Chairman. I, too, am anxious to hearing your testimony today and look forward to working with the Chairman on this issue.

Thank you, Mr. Chairman.

[The prepared opening statement of Mr. Bruce follows:]

OPENING REMARKS
THE HONORABLE TERRY L. BRUCE
NSF AUTHORIZATION HEARING
MARCH 13, 1991

THANK YOU, MR. CHAIRMAN. I WOULD LIKE TO WELCOME DR. LARRY ECONOMY, PROFESSOR OF MATERIALS SCIENCE AND ENGINEERING AT THE UNIVERSITY OF ILLINOIS. THE UNIVERSITY OF ILLINOIS IS IN THE 19TH CONGRESSIONAL DISTRICT OF ILLINOIS, AND IT IS A SOURCE OF PRIDE FOR ALL THOSE WHO RESIDE THERE. I AM GLAD DR. ECONOMY COULD BE HERE TODAY.

FURTHERMORE, I WOULD LIKE TO ONCE AGAIN STRESS THE IMPORTANCE OF THE NATIONAL SCIENCE FOUNDATION TO THE VERY EDUCATIONAL AND TECHNOLOGICAL FRAMEWORK OF THIS COUNTRY. THE CONTRIBUTIONS OF THE NSF TO THE MANY UNIVERSITIES, RESEARCH CENTERS, AND OVERALL EDUCATION OF THE AMERICAN PEOPLE CANNOT BE MEASURED MONETARILY. THE SUCCESS WILL BE MEASURED SOMEDAY BY THE COMPETITIVENESS OF THIS COUNTRY IN WORLD AFFAIRS.

MUCH OF THE MONEY THAT DOES COME FROM THE NSF GOES TO OUR UNIVERSITIES AND THEIR RESEARCH CENTERS. I LOOK FORWARD TO HEARING FROM OUR WITNESSES, ALL OF WHOM HAVE COME TO US FROM PRESTIGIOUS INSTITUTIONS, AND ALL OF WHOM CAN EXPLAIN TO US WHAT THE NSF DOES FOR THIS COUNTRY.

THANK YOU.

Mr. **Boucher**. The Chair thanks the gentleman. We welcome now our first panel of witnesses: Mr. Joe B. Wyatt, Chancellor of Vanderbilt University, and Vice-Chair of the Advisory Committee of the Higher Education Colloquium on Science Facilities; Dr. Albert W. Johnson, Vice-President for Academic Affairs, San Diego State University; Dr. Ed Przybylowicz, Senior Vice President and Director of Research at Eastman Kodak; Dr. David G. Whitten, Chairman and Professor, Department of Chemistry, University of Rochester.

Without objection, your prepared statements will be made a part of the record, and we would welcome your oral summary of those statements. The Chair would ask that the witnesses please keep their oral summaries to five minutes, and that will enable us then to propound questions.

We welcome you this morning, and Dr. Wyatt, we will begin with you, sir.

STATEMENT OF DR. JOE B. WYATT, CHANCELLOR, VANDERBILT UNIVERSITY, AND VICE CHAIR, ADVISORY COMMITTEE OF THE HIGHER EDUCATION COLLOQUIUM ON SCIENCE FACILITIES

Dr. **Wyatt**. Thank you, Mr. Chairman. My name is Joe Wyatt. I am Chancellor and Chief Executive Officer at Vanderbilt University. My testimony today is on behalf of the Higher Education Colloquium on Science Facilities, which is chaired by Senator Terry Sanford.

I appreciate the invitation to share my views on these issues in setting priorities within Federal research funding, and it is a special pleasure to be here with this committee, since I have served as co-chairman of the Colloquium with four other members of Congress, including Senator John Danforth and two members of this subcommittee, as well as the Chairman of your full committee, Representative George Brown.

The Colloquium was established in March of 1990 to seek consensus on policies and actions needed to ensure that the Nation has an adequate and appropriate supply of academic science and engineering facilities for the future. Let me say at the start that the Colloquium expresses its support for restoration of, and adequate funding for, the NSF research facilities program.

According to the latest survey, the amount of deferred repair, maintenance and new construction for new facilities in America's universities and colleges has increased 40 percent since 1988 to a level of about $12 billion. The consequences of continuing to neglect this backlog of needed facilities are significant will inevitably cost our Nation further loss of leadership in a growing number of fields in science and technology. I don't believe I have to go any further than the laboratories at my own institution to document this.

Just to give you one example, Vanderbilt's Department of Electrical Engineering is located in a building that is 38 years old. It lacks insulation from vibration. The water supply has iron deposits due to inadequate plumbing, and it does not have electrical power adequate to handle the requirements of critical research equipment.

Because of this situation, we have actually had to shut down a chip furnace, and we can't do some of the things we would like to do because of the limitations on vibration and the water supply. This is true in most other universities. You will find facilities that are obsolete and need some sort of work just to be used for modern instrumentation.

I think it is urgent that we do something about it immediately, because in the United States, as opposed to most of the developed countries, other half—60 percent—of the research and development is conducted in universities, financed by the Federal Government. Another six percent is financed by industry and the balance of the money comes from State sources and from institutional resources.

Our research institutions already contribute a good deal of facilities on our own. Half the funds for repair and renovation of academic science and engineering research facilities comes from the institution's own resources, either coming through the taxpayers of the State, or philanthropy is usually used in private institutions.

In addition to devoting substantial portions of their own resources to the problem, research institutions are seeking creative solutions to trying to reduce the costs of these facilities. The Colloquium, for example, has a program now to survey the Nation, both corporate research laboratories and university research laboratories, to see if we can arrive at a formula for minimum cost in construction of these facilities. We believe we may find evidence that may cause us to seek some relief from antique building codes that could save us some money.

This brings me to the question of funding for NSF's infrastructure programs. I congratulate the Administration on the instrumentation initiative of $50 million. But I do find it puzzling, that at a time when 17 percent of expansion of NSF's research funding is proposed for fiscal year 1992, its budget provides no funding for facilities modernization. This program has been the Federal Government's only promising response, of which I am aware, to the general academic research facilities problem in 20 years. It has been funded at about $20 million annually for the past two years, a fraction of its current $250 million annual authorization.

We recommend restoration of that. There are a number of reasons for making this modest investment, and let me just quickly go through four. First of all, the need is well documented. The amounts are very modest, relative to the total. The Academic Research Facilities Modernization Program has had an excellent response, despite its short life. The first round of competition alone received more than 425 proposals requesting $320 million.

Of the $39 million awarded to 78 universities, colleges and private nonprofit institutions in 37 states was augmented by $61 million in matching funds, coming from those entities. This is an important point. This means that in this competitive arrangement, for every $2 awarded by the Federal Government, the institutions came up with another $3 from non-Federal sources. This is a bargain for the Federal Government in dealing with these scarce facilities.

Third, the practice of earmarking, or designating funds for facilities without any sort of competitive review of judgmental review has reached an epidemic state. According to the Chronicle for

Higher Education recently, the number is almost a half billion dollars this year. In the last three years, we have seen virtually a doubling each of year of the practice of earmarking.

Let me give you one example from the Chronicle. We are asking here for $20 million for this program in NSF. One institution alone, Iowa State University, is scheduled for earmarks of almost $30 million, $16 million solely for use at Iowa State, and another $12 million or so for Iowa State and other universities. I am not picking on Iowa State, except that they seem to have a lion's share of the earmarked funds this year. Two other colleges and universities, Boston College and Drake, account for $2 million alone in two earmarks for science facilities.

This is not the way to create good science. To me it is analogous to telling a child that the way to get an A is to know the principal, rather than take the test. That's not the way to create the infrastructure we need in this country.

It is clear, fourth, that the ability to do leading edge research is more and more depending on adequate instrumentation and adequate facilities. State of the art instrumentation is paramount, and I personally can't draw the line between instrumentation and facility. Let me give you an example. At Vanderbilt, two of our newest research instruments are a Free Electron Laser and a Positron Emission Tomography Scanner. Each has required the construction of a very sophisticated facility tailored to the special needs of those instruments.

Without those special facilities, you can't use the instruments—special power supplies, cooling, and shielding. So there is no clear line I can distinguish between instrumentation and facilities. I think to try to strain at developing one places serious limitations on what we really need to do for our research facilities and instrumentation.

Therefore, it would seem prudent to make research facilities modernization a continuing program at NSF, to restore those funds that have been removed. I do again congratulate the Administration on the recognition of need for instrumentation. We certainly do need it. But I believe these needs are in the aggregate.

I thank you very much for your attention, and I will be pleased to answer any questions.

[The prepared statement of Dr. Wyatt follows:]

TESTIMONY

PRESENTED BEFORE

THE SUBCOMMITTEE ON SCIENCE
OF THE
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

PRESENTED BY

JOE B. WYATT, CHANCELLOR
VANDERBILT UNIVERSITY

ON BEHALF OF

THE HIGHER EDUCATION COLLOQUIUM ON SCIENCE FACILITIES

MARCH 13, 1991

My name is Joe Wyatt. I am Chancellor and CEO of Vanderbilt University where students from each of your states have been and are being educated. My testimony today is on behalf of the Higher Education Colloquium on Science Facilities, which is chaired by Senator Terry Sanford. Thank you for the invitation to share my views on critical issues in setting priorities within federal research funding. It is a special pleasure to be here with this committee since I have served as co-chairman of the Colloquium with four other members of Congress, including Senator John Danforth and two members of this subcommittee, Representatives Sherwood Boehlert and Tim Valentine, as well as the Chairman of your full committee, Representative George Brown, Jr.

The Colloquium was established in March 1990 to seek consensus on policies and actions needed to ensure that the nation has an adequate and appropriate supply of academic science and engineering facilities for the future. A description of the colloquium is appended to my testimony.

The subject of today's hearing focuses on the core of the Colloquium's concern. I have been asked to comment on the importance and relative priorities of the National Science Foundation's activities pertaining to research infrastructure. Specifically this covers its two-year old program for modernization of research facilities and its proposed instrumentation program. I have also been asked to comment on the effects on academic research of the lack of adequate facilities and instrumentation.

Let me say at the start that the Colloquium expresses its support for restoration of and adequate funding for the NSF research facilities program.

Before giving you details and reasons for our position, I want to briefly state the need the NSF facilities program is intended to address. The problem of obsolescence, inadequacy, and disrepair in the academic research infrastructure has been well documented over the past decade in reports by several prestigious, broad-based groups such as the White House Science Council, the Government-University-Industry Research Roundtable of the National Academy of Sciences, and the Council on Competitiveness, as well as by the National Science Foundation and various associations of universities.

According to the latest survey reported by NSF, the amount of deferred repair, maintenance, and new construction for research facilities in America's universities and colleges has increased 40 percent from 1988 to 1990 to a level of about $12 billion dollars. The consequences of continuing to neglect this backlog of needed facilities are significant and will, inevitably, cost our nation further loss of leadership in a growing number of fields in science and technology. I do not have to go further than the laboratories at my own institution to document this.

Our department of electrical engineering, for instance, is housed in a building that is 38 years old; it lacks insulation from vibration, its water supply has iron deposits due to inadequate plumbing, and it does not have electrical power adequate to handle the requirements of critical research equipment. Because of the power situation, for instance, we had to shut down a furnace for making microelectronic devices. This is an area of research, which, as you know, is extremely important to the future competitiveness of our high technology industries. And there are many more examples in the documents I have provided for the record.

Unfortunately, many universities and colleges have similar problems. Research experiments and programs are being suspended, postponed, delayed, and canceled because of inadequate or obsolescent facilities in institutions, both large and small, across the nation.

The effects of facility obsolescence or unavailability extend beyond missed research opportunities. Ultimately lack of adequate facilities discourages and even prevents the development of first-rate faculty and graduate students. I have given documentation of other effects in the materials I have provided for the record.

The conditions I have been describing have been apparent for some time. To explain why it is urgent to do something about it immediately, I want to begin with a fact that is sometimes taken for granted. That is that in the United States, as in no other industrialized nation, basic scientific and engineering research is principally carried out in America's universities and colleges. About 60 percent of the research and development conducted in universities is financed by the federal government. Another 6 percent is financed by industry.

Despite this substantial reliance on academia for performing research in the national interest, federal support for research facilities, in terms of constant dollars, is about half what it was in the mid-1960s. And NSF estimates that industry contributes less than $200 million annually for all academic capital projects, research facilities included, even though industry's contribution has grown in recent years.

The leadership of our organization recognizes that the federal government alone cannot be expected to solve the research facilities problem. For that reason we are developing a national strategy for continuing support of research facilities that will embrace all parties concerned, including the universities, the states, the private sector, and the federal government.

Our research institutions already contribute substantial resources of their own. For instance, more than half of the funds for repair and renovation of academic science and engineering research facilities in 1988-89 came from institutions' own resources, according to an NSF survey. Most of the remaining funding for renovation came from state funds in the case of public institutions and tax-exempt bonds and philanthropic donations in the case of private institutions. With respect to funds for new facilities construction, private institutions obtained 70 percent of their construction funding from donations and debt financing, while public institutions acquired almost half of their construction funding from state and local governments.

In addition to devoting substantial portions of their own resources to the problem, research institutions are seeking creative solutions to the problem. The Colloquium, for instance, has set up a task group to find more efficient and less costly methods for planning and building research facilities while making them conform to new environmental, health, and safety regulations. In some cases, we may seek relief from obsolete and overly restrictive building codes.

Despite the promise of these efforts for the future, it is our belief that a comprehensive program for academic research facilities must have the participation and leadership of the federal government to succeed. Toward this end, the Congressional members of the Colloquium sent a letter to President Bush in July 1990 urging him to take the lead in developing the elements of a national strategy. That letter is appended to my testimony.

This brings me to the question of funding for NSF's infrastructure programs. For a number of reasons I find it puzzling that at a time when a 17 percent expansion of NSF's research funding is proposed for FY 1992, its budget submission provides no funding for the Academic Research Facilities Modernization Program.

In our view, this program has been the federal government's only promising response to the general academic research facilities problem in 20 years. And it has been funded at about $20 million annually for the past two years, a fraction of its current $250 million annual authorization.

We recommend restoring and increasing funding for this program to its authorized level. While recommending full funding, which is no more than half of the amount urgently requested by the Packard-Bromley report in 1986, we recognize that reality this year might require reducing this in some amount. The reality of the future of science, however, almost cries for several times the $20 million appropriated for the past two years. Facilities funding, in my view, should be regarded as a necessary investment in the future health of the U.S. research capability. There are a number of other reasons for making this modest investment. Let me address four of the major ones.

1. The need is well documented, and the amounts required are very modest compared to the need. Moreover, the critical role of facilities in enabling our scientists and engineers to continue to do first-class research and train future scientists and engineers has never been more urgent.

2. The Academic Research Facilities Modernization Program has had an excellent response despite its short life. In the first round of competition, more than 425 proposals were received requesting $320 million. The $39 million awarded to 78 universities, colleges, and nonprofit institutions in 37 states was augmented by $61 million in matching funds. This means that for every $2 awarded, the government leveraged $3 in nonfederal resources. Experience with similar leveraged programs shows that the leveraging continues after awards are made.

3. The practice of earmarking, or voting funds for individual research facilities without merit review, is increasing. In the absence of a broad, competitively reviewed program of infrastructure awards, earmarks are estimated to be in excess of $400 million for this fiscal year, or 20 times the annual appropriation for the NSF facilities program. I deplore the practice of earmarking funds for research facilities without competitive review. I have testified on the subject before the Congress on several occasions. That testimony is in the record and still stands. The practice undermines the quality engendered by competitive proposals expertly judged. It also loses the financial leverage so often possible as a result of competition. In sum, earmarking is the road to ruin for research facilities.

4. The ability to do leading edge research is becoming increasingly dependent on the ability of universities to acquire instrumentation and build adequate facilities. Planning for research projects in many advanced fields of science and engineering increasingly involves planning for new instrumentation and facilities. Since NSF provides a significant proportion of federal funds for basic research in academia, investigators who win research awards on merit should not have to be turned down because their institutions cannot find funds for the necessary modernization of facilities. This is not a matter of conjecture. Again, I turn to my own university for examples. The lack of facilities has been responsible, in part, for terminating a proposal to buy a large Van de Graff accelerator and responsible for the delay in creating an institute for molecular medicine. It makes no sense for the National Science

Foundation to have funds for research, funds for instrumentation, but no funds for general-purpose facilities.

Turning to the proposal to establish a new state-of-the-art instrumentation program, I can genuinely applaud the wisdom of a program to satisfy this critical need. I am puzzled, however, by what appears to be an attempt to draw a sharp distinction between the need for research facilities and the need for research instrumentation. The two are mutually dependent and virtually inseparable. Laboratory benches with "clean" electrical power, a pure water supply, and a host of other services including bottled gases and the like are a prerequisite for the instrumentation of much science and engineering research, particularly for small projects. Fume hoods are mandatory for many experiments in both small and large projects. Supercomputers require a host of special facilities including sophisticated networks to make them accessible by their research users.

For large projects, the special facilities required for state-of-the-art instrumentation are paramount. At Vanderbilt, for example, two of our newest research instruments are a Free Electron Laser and a Positron Emission Tomography scanner. Each has required the construction of a sophisticated facility tailored to the special needs of the instrument. I won't take the time to describe these details here, but the cost of each facility has run in the millions of dollars.

In sum, virtually no research instrumentation can be installed and utilized without requiring facilities adequate for the purpose. And in most cases, the facility requirements of today's research instrumentation are very sophisticated and often quite expensive. From my perspective on the relationship between research, instrumentation, and facilities, it makes sense, if funding for expensive, sensitive equipment is to be expanded, to ensure that there will be adequate housing for it.

Therefore, it would seem prudent to make research facilities modernization a continuing program at NSF. There is precedent for this. In the early 1980s, NSF responded to reports of a documented deficit in instrumentation by steadily increasing the share of its expanding research base that it allocated to instrumentation. The share of NSF research awards allocated to instrumentation has increased from about 6 percent in 1979 to about 12 percent in 1990. This is entirely necessary and appropriate. Investment in facilities ought to have similar treatment.

For the reasons I have outlined briefly, I strongly urge your committee to advocate establishment and strengthening of merit-based, leveraged federal facility programs not only at NSF but at other federal agencies with research programs.

Thank you for your attention. I will be pleased to respond to any questions you might have.

APPENDIXES

Appendix A	Higher Education Colloquium on Science Facilities Description
Appendix B	Congressional Letter to President Bush, July 26, 1990

Appendix A

HIGHER EDUCATION COLLOQUIUM
ON
SCIENCE FACILITIES

THE PROBLEM: The deterioration and obsolescence of the nation's academic science and engineering facilities are widely recognized. Consensus exists in government and academia that the situation now threatens the nation's research enterprise and the quality of new scientists, engineers, and research personnel. In 1986 the White House Science Council estimated that it would take $1 billion a year for 10 years, over what is currently being provided, to address the shortfall in university infrastructure. The shortfall has not diminished since then.

THE COLLOQUIUM: The Higher Education Colloquium on Science Facilities is motivated by concerns that there is a need for greater investment in university research facilities to meet national goals. The growing practice in Congress of earmarking federal appropriations for facilities at particular universities is a symptom of the underlying problems caused by years of under-investment in academic laboratories. Many policy makers believe that earmarking does not adequately meet the nation's needs, but does disrupt orderly planning and allocation of resources. Because others disagree, contending that the present system of allocating federal funds is inadequate, if not unfair, a consensus on the issues continues to elude Congress and the university community.

OBJECTIVE: The Colloquium will seek consensus on policies and actions needed to ensure that the nation has an adequate and appropriate supply of academic research facilities for the future. It will meet periodically to hear experts on the issues, review findings of recent studies, and discuss pros and cons of options for changing current facility financing practices. Further study of the problem and its dimensions is not needed. What is needed now is to move from ideas to action.

LEADERSHIP: The Colloquium is chaired by Senator Terry Sanford. Co-chairs are Representative George Brown, Jr., Senator John Danforth, Representative Sherwood Boehlert, Representative Tim Valentine, and Chancellor Joe Wyatt of Vanderbilt University.

MEMBERS: Chancellor Richard Atkinson of the University of California, San Diego; President John Byrne of Oregon State University; President John Crecine of Georgia Institute of Technology; President Edward Malloy of Notre Dame; President Kenneth Pye of Southern Methodist University; Chancellor Donna Shalala of the University of Wisconsin, Madison; and President Harold Shapiro of Princeton University. In addition to its 13 regular members, about 50 members of Congress serve as Consultative Congressional Members to the Colloquium.

STAFF: Patricia Warren, Director; Constance Bellamy, Administrative Assistant Offices at 318 Massachusetts Avenue, NE, Washington, DC, 20002. Telephone 202/547-8715.

Appendix B

Congress of the United States
Washington, DC 20515

July 26, 1990

The Honorable George Bush
The White House

Dear Mr. President:

We write to urge you to act on a critical national problem: the evident crumbling of the infrastructure vital to research in our colleges and universities.

The strength of these institutions is a cornerstone of the nation's international competitiveness and economic well-being, the health of our citizens, the quality of our environment, and our national security. But the breakdown of academic research facilities is eroding the schools' ability to respond to needs in those areas. It is threatening their ability to do first-rate research and to educate new scientists and engineers at both the undergraduate and graduate levels.

The persistent underinvestment in the academic research infrastructure is beyond debate. The Packard-Bromley report, issued by the White House Science Council in 1986, estimated that $10 billion over 10 years was "the necessary minimum" investment needed from all sources to restore the infrastructure to acceptable condition. The National Science Foundation estimated that in 1988-89 universities needed $11.7 billion for improvement of facilities; only $3.1 billion was available. Yet today, federal spending on academic research facilities, in constant dollars, is less than half of its level in 1966.

For more than 20 years we have had no policy for federal investment in academic research facilities. Because we have had no comprehensive, adequately funded plan, funds earmarked by Congress for such facilities have jumped 20-fold during the past decade. In fiscal year 1987, roughly half of the $200 million in federal obligations for academic R&D plant resulted from earmarking.

We applaud your stated goals in science and technology, such as doubling the National Science Foundation budget, making the R&D tax credit permanent, placing greater emphasis on science and mathematics education, and providing support for investment in enabling technologies aimed at improving U.S. economic competitiveness.

We urge you now, as a national priority, to develop a strategy for investment in undergraduate and graduate facilities for research and research training and to implement it in the budget for fiscal year 1992. The strategy should comprise a mix of mechanisms, in part to recognize the multiple goals of furthering agency missions, renewing the physical plant at existing centers of excellence, and creating new centers of strength.

The Congress, several administrations, and the academic community have explored many possible responses to the crisis in the research infrastructure. Some responses that the federal government could make are now widely supported and, we believe, should be considered as part of a comprehensive plan. These measures are:

- Fund the NSF Academic Research Facilities Modernization matching grant program at its authorized level of $250 million and broaden it to include new construction; establish a similar competitive matching grant facilities program in NIH.

- Implement promptly reforms in the treatment of research facilities in indirect cost recovery now being negotiated between OMB and representatives of higher education. These reforms include more realistic allowances for use of research facilities under federal grants and contracts which recognize the technological obsolescence of such facilities, and the possibility for universities to switch without penalty from the use allowance method of cost recovery to depreciation.

- Restore tax incentives by excluding gifts of appreciated property from the alternative minimum tax and by removing the $150 million cap on tax-exempt debt for private institutions.

- Fund matching grant, loan, loan guarantee, and interest subsidy programs authorized under Title VII of the Higher Education Act for research and research training facilities at graduate and undergraduate institutions.

Our colleges and universities must have proper facilities for research and research training. Undergraduate and graduate programs in science and engineering today are not attracting enough of the most talented U.S. students. Further, the eroding research environment is deflecting the best students from academic careers, and this trend will intensify until our citizens are made to realize that the quality of the research environment is vital to our future.

If we are to lead the world in technology development, and all the benefits such leadership implies, we can no longer defer the badly needed investments in academic capabilities for doing research and educating future scientists and engineers. Fresh policies must be formulated to guide our investments in the academic research infrastructure. And decisions on allocating the funds must be made wisely, openly, and competitively, ensuring that all types of institutions participate appropriately.

We know that all parties—state governments, the private sector, and colleges and universities, as well as the federal government—must do their parts, and we stand ready to work with you in developing a comprehensive plan. But only you, Mr. President, can provide the leadership and broad view needed to integrate such a strategy into an overall policy for science and technology. We believe that the Congress must, and will, work with you to achieve this essential goal.

Sincerely,

Terry Sanford

Terry Sanford
U.S. Senator

John C. Danforth
U.S. Senator

George E. Brown, Jr.

George E. Brown, Jr.
Member of Congress

Sherwood L. Boehlert
Member of Congress

Quentin Burdick

Quentin N. Burdick
U.S. Senator

Robert C. Byrd

Robert C. Byrd
U.S. Senator

John Chafee

John H. Chafee
U.S. Senator

Pete V. Domenici

Pete V. Domenici
U.S. Senator

John Glenn

John Glenn
U.S. Senator

Al Gore

Al Gore
U.S. Senator

Orrin G. Hatch

Orrin G. Hatch
U.S. Senator

Daniel K. Inouye
U.S. Senator

Sam Nunn

Sam Nunn
U.S. Senator

Jim Sasser

Jim Sasser
U.S. Senator

Arlen Specter

Arlen Specter
U.S. Senator

Academic Research 7/27/90

Mark O. Hatfield
U.S. Senator

Dick Lugar

Richard G. Lugar
U.S. Senator

Lee H. Hamilton
Member of Congress

Tom McMillen
Tom McMillen
Member of Congress

Leon E. Panetta
Member of Congress

David Price
David Price
Member of Congress

Don Ritter
Don Ritter
Member of Congress

Robert A. Roe
Member of Congress

Tim Valentine
Member of Congress

Doug Walgren
Member of Congress

Norman Y. Mineta
Member of Congress

Bob Traxler
Bob Traxler
Member of Congress

APPENDIXES FOR THE RECORD
TESTIMONY OF CHANCELLOR JOE WYATT
MARCH 13, 1991

- Letter from Chancellor Joe Wyatt, Vanderbilt University, to President Bush, September 14, 1990
- Letter from President Frances D. Ferguson, Vassar College, to Senator Terry Sanford, August 23, 1990
- AAU and NASULGC Ad Hoc Committee on Academic Research Facilities, *University Research Facilities: A National problem Requiring a National Response, Appendix E: Statements by Public and Private Universities on Research Facilities Needs in Six Fields* (June 1989)

VANDERBILT UNIVERSITY
NASHVILLE TENNESSEE 37240
TELEPHONE (615) 322-7311

Office of the Chancellor • Suite 211, Kirkland Hall • Direct phone 322-2168

September 14, 1990

The President
The White House
1600 Pennsylvania Avenue
Washington, D.C. 20500

Dear Mr. President:

On July 26, 1990 a letter on the subject of research facilities in colleges and universities, signed by 15 members of the Senate and 12 members of the House of Representatives, was sent to you. Those of us in America's research universities who have been struggling to meet research facilities needs applaud the letter, and I want to join in urging your serious consideration of its proposals.

Let me give you just a few illustrations of how the problem of inadequate research facilities affects Vanderbilt University.

- In the Department of Physics, a proposal to procure a large Van De Graff accelerator was terminated, in part because of a lack of a facility in which to place it if it could be obtained. And yet, this is an instrument that we understand is readily available to researchers in Japan who are challenging American researchers for competitive advantage. Competitive advantage in research that will lead to competitive advantage in products and services.

- The Department of Electrical Engineering at Vanderbilt is housed in a building that is 38 years old. Although the Department has been successful in its effort to acquire some modern equipment, the building does not provide sufficient electrical power to handle the loads of critical research equipment. For example, a furnace for making microelectronic devices cannot be utilized in this building because of insufficient electrical capacity. Microelectronic devices are the heart of computer and electronics capability and thus are critically important in the development of high technology. Other problems related to the obsolescence of the building range from the absence of vibration isolation to iron deposits occurring in the water supply as a result of aged and inadequate plumbing. Vice President Quayle could tell you firsthand about the state of our engineering building; we were pleased to have him in the building last year for the announcement of the University Consortium for Research on Electronics in Space.

- In Vanderbilt's Medical Center, it has been necessary to delay the creation of a Department of Physical Medicine, the expansion of the Department of Opthamology, and the creation of an Institute of Molecular Medicine, all because facilities have not been available to house their research programs.

I do want you to know that we are using all the resources at our disposal for addressing facility needs in the absence of needed federal support. For example, in order to provide a facility to house a free electron laser, one of only three to be funded by the federal government, Vanderbilt invested $2.6 million of its funds. And we did so without hesitation because this instrument and facility will benefit cancer research in addition to numerous other critical research topics being examined by physicists, chemists, biochemists and physicians.

I do not ask for unilateral government handouts to solve these problems and I have not sought non-competitive congressional earmarks to finance facilities as some others are doing. What I am asking you to do is support initiatives that will allow us to fend for ourselves in a competitive environment. I appreciate your support for making the Research and Development Tax Credit permanent, one example of an action that allows us to develop joint projects with American businesses. These joint projects, in the aggregate, have already offset their cost to the government with a handsome rate of return over time. In addition, such joint projects help us deal with one of America's most difficult problems in the highly competitive economic and military environment of today's world: the rapid transfer of research discovery from American university laboratories to American products and services. And there are other actions that will give us a chance to be competitive at minimal cost to the federal government. A removal by Congress, with your encouragement, of gifts of appreciated property from the alternative minimum tax and elimination of the $150 million cap on tax exempt debt for private institutions, would greatly assist Vanderbilt in raising capital from donors and borrowing for needed research facilities. The cost to the federal government of these changes would be a small fraction of the dollar value and the benefit to the nation of these facilities. All of the other proposals contained in the letter of July 26 represent ways in which changes in federal policy would enable the construction of research facilities at a cost to the government of much less than their total cost.

I pledge my own help and support as you move forward in the ways proposed in the July 26 letter. Much is at stake, and I hope that you will give these matters the attention and commitment that they deserve.

Sincerely,

Joe B. Wyatt

JBW:sah

VASSAR COLLEGE
POUGHKEEPSIE·NEW YORK 12601
Office of the President

August 23, 1990

The Honorable Terry Sanford
United States Senator
Chairman, Higher Education Colloquium on Science Facilities
United States Senate
Washington, D.C. 20510

Dear Senator Sanford:

I respond with great interest to your questions relating to the state of academic science facilities in higher education and the federal government's role in supporting the infrastructure needs on which scientific excellence depends. I commend you for your leadership of the Higher Education Colloquium on Science Facilities.

By way of introduction, I want to state a few facts about science and its place at Vassar College. The College has a longstanding tradition of excellence in undergraduate science education, consistently ranking among the top ten institutions in the country in the preparation of future women Ph.D.s in the sciences (until the advent of co-education at Vassar in 1969) and currently rated 14th among private, four-year institutions in the training of young men and women who later became Ph.D. scientists. Our full-time faculty in the behavioral, physical, and mathematical sciences represent one-quarter of the entire instructional staff; they are strong, research-oriented scientists and actively involve students in their research programs; a substantial number of our science faculty hold research grants with federal agencies. The two most recently constructed academic buildings at Vassar are science facilities, and scientists are major occupants of eight instructional and research buildings on the campus. Since 1986, the College has maintained a highly successful faculty-student research program involving about 65 total participants each summer. In sum, science is a thriving enterprise at the College.

For these reasons, the mission of the Higher Education Colloquium on Science Facilities is of special interest to Vassar.

I will begin my remarks with one sweeping generalization: excellent science is a terribly expensive enterprise and, increasingly, a budgetary factor that exceeds our annual operating resources and the generosity of our traditional donor constituency. A number of factors conspire to make this the case. The College wishes to remain highly competitive in the salaries offered to scientists already on staff. At the same time, we are being asked for higher and higher start-up costs by new scientists. The list of desirable scientific periodicals grows each year, but our library budget has now reached a point where some critical choices will need to be made. Our faculty and students require individual pieces of new equipment that cost hundreds of thousands of dollars.

In addition, the need to replace outdated instrumentation exceeds our ability to keep pace. Computer equipment of particular interest to scientists is now adequate, but we need to begin to plan strategically for its replacement. Maintenance contracts on science instruments and computer hardware cannot be universally assured. With the exception of our biology and chemistry buildings, all other science facilities predate World War II. A significant number were constructed before the turn of the century.

To maintain the quality of the existing infrastructure, we are told that institutions should plan to set aside each year 20% of the original purchase price of equipment for short-term maintenance costs and eventual replacement and to factor in about $3 per gross square foot annually for maintenance (exclusive of utility costs) of existing academic buildings. As a brief aside, these are expenses that federal indirect costs do not begin to cover.

Then there are many other indirect expenses. Undergraduate colleges, as well as major research universities, are now in the business of expending vital resources for animal colonies, visiting veterinarians, human subjects oversight committees, environmental control equipment, hazardous waste removal, and so on -- issues that grew out of the federal government's generous support of basic research and its legitimate interest in the quality of the research environment. These are right-minded concerns, but expensive propositions.

Let me address the specific topic of academic science facilities. Some examples from Vassar's own experience may be relevant. I mentioned earlier that the College's two most recently constructed academic buildings were science facilities. In 1972, Olmsted Hall for the Biological Sciences was completed at a cost of $4 million and provided 72,000 gross square feet of space. In 1984, the College opened Mudd Chemistry Building, offering 42,500 gross square feet of space, at a cost of $7.2 million. Several peer liberal arts colleges are currently constructing science facilities -- sometimes with much less space -- in the $20 million range. These are enormous investments and will require many-sided partnerships.

On our own campus, we are now considering strategies to deal with a host of science modernization problems, particularly in the physical sciences. Our observatory is a landmark structure erected in 1864 and associated with the founding of the College. While the old observatory is an important symbol of the place of science in the Vassar curriculum, it has a largely inoperative dome, houses substandard telescopes for contemporary astronomical research, and is situated in a highly lit part of the campus, thus hampering quality observational studies. The building housing geology was originally constructed in 1889 as a gymnasium; it was renovated in 1937 for geology and other College purposes. Existing laboratory space is not appropriate for the current curriculum and faculty research, and the HVAC systems are inadequate for the kinds of instrumentation geologists currently use in instructional and research experiments. Our physics building dates from 1926. Space needs are adequate at this time, but, as retirements accelerate, it is becoming clear that incoming physicists fresh from a postdoctoral experience will expect new kinds of equipment and different laboratory configurations. Our computer science department and academic computing center share the former College laundry, constructed in 1872 and last renovated in 1966. Our physiological psychologists and neuroscientists have inadequate laboratories and animal rooms in a 1928 academic building designed for a very different kind of educational experience.

We are making considerable headway with a number of these science facility and infrastructure deficiencies. The College has applied to the National Science Foundation's new Academic Research Facilities Modernization Program for a major grant in support of the modernization of our geology laboratories. We have targeted funds in our recently approved New York State educational facilities bond issue for improvements of the laboratory environment in experimental psychology and neuroscience and for modernization of the geology building. We are developing plans for a new observatory. A major foundation has awarded Vassar a five-year grant of $500,000 for scientific instrumentation. We are preparing a new application for a major piece of scientific instrumentation and are negotiating the long-term lease of a research-quality telescope. The College is currently participating in the Alfred Sloan Foundation program in computer literacy and quantitative reasoning, the Howard Hughes Medical Institute initiative in undergraduate science, and the Pew Trusts program of undergraduate science consortia. The Dean has given broad encouragement to the science faculty to seek funds from the Instrumentation and Laboratory Improvement Program at the National Science Foundation, and they have been successful. The senior officers are considering science equipment endowments and faculty-student research endowments as potential goals of an upcoming capital campaign. These are all salutary developments.

Nonetheless, single institutions cannot begin to address all current and prospective needs. As I see it, major improvements in the science facilities and the scientific infrastructure of American colleges and universities will ultimately depend upon a number of partners: institutional resource planning (whether based upon the endowments of private institutions or the state treasuries of public universities), generous alumnae/i, foundations and corporations, and the federal government.

We encourage the federal government to make far larger investments in academic science facilities. No other institution in this country commands the kind of resources that can result in broad-scale and relatively short-term improvements.

We particularly applaud the National Science Foundation for making a first major entry into the area of science facilities modernization and for instituting a rigorous process of peer review. Similar institutions competed with one another. Substantial planning by applicants was required. The guidelines remained appropriately flexible to meet the particular science needs of the individual institution. This was a most heartening initiative after an unfortunate period of special interest lobbying and earmarking grants for specific institutions. We hope that similarly rigorous, peer-reviewed facility initiatives will emerge from the National Institutes of Health and the mission-oriented agencies engaged in scientific and technological research.

As we applaud new initiatives, we also need to be mindful of the informed public's response to current projects in which the federal government is engaged. A number of scientists, often with mixed motives, have argued in editorial columns of the national press and in leading scientific journals that federally funded academic science is currently suffering from "gigantism." Much pen and ink, as well as federal dollars, have gone to support supercomputers, space stations, enormous weapons systems, the massive human genome project, supercolliders, the supermagnet center, and the like. There is probably good and bad in all these initiatives. It might be pertinent to ask if these large-scale initiatives are solving central problems and creating common, long-term resources for exploration of other critical scientific topics. The greatest fear of many scientists, frequently voiced in smaller institutions, is that small-scale science and vital basic research may be displaced, both in the short term and the long run, by highly publicized "mega" projects. Not all important discoveries have required massive doses of dollars.

As we observe scientific practice today, I am doubtful that the romantic model of the solitary experimentalist or theoretician working alone in his or her laboratory late at night is congruent with contemporary scientific practice. Our scientists pair up with colleagues in other disciplines; they involve their students; they collaborate with scholars at other universities, federal laboratories, and industrial research institutes; they seek time on distant super computers and large-scale telescopes. I wonder to what degree scientific research can continue to be practiced and funded within single institutions and individual laboratories. I wonder to what degree we need to pool resources and encourage partnerships. This idea, I realize, goes counter to the very notion of our institutional autonomy and to the self-image of many scientists.

As a final observation, I would urge the members of the Colloquium not to lose sight of the relationship between academic facilities and their ultimate beneficiaries - the continuing stream of young scientific talent who, we hope, will replace and expand the pool of today's academic scientists, government researchers, and corporate technologists. You are familiar, I am sure, with the 1985 Oberlin report on science at private liberal arts colleges; the 1986 task force report of the National Science Board on undergraduate science, mathematics, and engineering education; the 1988 Franklin & Marshall study of baccalaureate origins of doctorate recipients; and a similar 1989 study conducted by Georgetown for another segment of higher education. I refer to these studies because I firmly believe that the bedrock of science in this country is at the undergraduate level.

It is during these four years of baccalaureate study that the raw intellectual talent of young women and men is nurtured and shaped toward the goals of professional scientific competence. In these years, students master the basic facts of science, learn the modes of inquiry, refine their powers of analysis through observation and experimentation, become acquainted with the techniques of sophisticated instrumentation, and begin to test their own hypotheses through independent study, the thesis, and summer research. It should be a privileged moment in the maturation of a scientist, when the scientific imagination still moves laterally and when parallels can be drawn freely, without the stigma of professional labels, from knowledge acquired in a statistics course, a chemistry lab, and a geology field trip.

I hope that federal science policy will continue to recognize these vital contributions of undergraduate science education to the development of scientific talent. Graduate schools, corporate laboratories, and federal research centers depend upon us. We do fine research; we excel in research training. Our leading liberal arts colleges contribute a disproportionate share of the future scientific leadership. In this respect, it is critical in designing federal programs that focus on academic science facilities to differentiate among the various categories of higher education and, accordingly, to ask schools to compete with their peers for funding.

There are many specific questions raised in your letter that I have left unanswered. I know that you will be calling various experts to testify before the panel and hope that liberal arts colleges will be appropriately represented in that group. On behalf of Vassar, I offer hearty support to the work of the Higher Education Colloquium on Science Facilities. We shall look forward to participating in any follow-up surveys and to learning the final results of your deliberations.

Thank you for the invitation to comment on government science policy and its relation to higher education.

Sincerely,

Frances D. Fergusson

Frances D. Fergusson
President

University Research Facilities: A National Problem Requiring a National Response

The Ad Hoc Committee on Academic Research Facilities

Association of American Universities
National Association of State Universities and Land-Grant Colleges

June 1989

Introduction

The National Science Foundation shortly will submit to Congress a report on academic research facilities. The report will address questions posed by Congress last year in the Foundation's FY 1989-FY 1993 Authorization Act, which, in part, established a new NSF Academic Research Facilities Modernization Program. Recently, in preparation for that report, the Foundation's Research Facilities Office invited AAU and NASULGC to address several issues related to research facilities needs of universities. In late April AAU and NASULGC prepared and distributed ten questions (Appendix A) to the executive heads of 56 AAU member institutions and the NASULGC legislative network with a request for a response within two weeks; 45 universities responded (Appendix B).

On May 17 an ad hoc committee (Appendix C) met with Mr. Richard Green, Director, and Mr. William Cole, Executive Officer, of the Foundation's Research Facilities Office. The Committee, informed by the responses of our member institutions, then prepared this brief response to the Foundation's request for the associations' views. Volumes could be written in response to the questions posed; in fact, several already have been written, and so we do not intend to replow fit ground. Instead, this summary statement attempts to restate briefly the context and consequences of the academic research facilities deficit, to highlight the factors contributing to the problem, and to suggest an appropriate policy framework to respond to it.

The associations extend their appreciation to all who answered their request for assistance. The Ad Hoc Committee made extensive use of those responses.

APPENDIX E

STATEMENTS BY PUBLIC AND PRIVATE UNIVERSITIES ON RESEARCH FACILITIES NEEDS IN SIX FIELDS

Biological Sciences 1
Chemistry 6
Engineering 9
Environmental Sciences 15
Materials Sciences 16
Physics 17

Biological Sciences

BRANDEIS UNIVERSITY

Further research programs in these areas are hampered at Brandeis University. There is now no further available space anywhere in the current buildings for increased research activities due to limitations on the facility. Currently, hallways are being used for desks, freezers, refrigerators, centrifuges and other equipment. The last shell space is being renovated to house a new Structural Biology group. Teaching labs, where possible, are being converted to research space.

CASE WESTERN UNIVERSITY

In the area of genetics, until recently research using animals was focused on drosophila (fruit flies) and bacteria in culture. Recent breakthroughs have made it possible to move to a mammalian model (the mouse) but very large colonies are required. Until an institution can find the resources to invest in the animal facility environments to support such laboratory animals, research cannot be conducted in this area. Although limited, support for animal facilities improvement or creation of facilities for AIDS research from N.I.H. has been a very important government initiative to help make this type of research possible.

THE JOHNS HOPKINS UNIVERSITY

AIDS: A large program of AIDS and AIDS-related research at Johns Hopkins is limited and impeded by obsolete facilities, and modernization and renovation funding is largely unavailable. Research involving the live HIV virus requires P3 (Physical Containment Level 3) laboratory facilities: isolation laboratories with negative air pressure control and maintenance capability; air locks; emergency isolation capability; separate and isolated ventilation systems; lockers and showers for staff; special aerosol containment hoods; non-public thoroughfares and hallways; etc. The present Hopkins research faculty would probably expand AIDS research activities to nearly double its present level (approximately $30 million annual expenditures) if it were possible to upgrade present facilities. Faculty simply do not respond to requests for research proposals in areas of high interest to them because of facilities limitations. The effect of this is that much potentially important AIDS research is either deferred, not done at all, or not done as rapidly or as well as it might be done.

MICHIGAN STATE UNIVERSITY

Modern molecular biology is becoming a powerful tool in basic animal sciences. Our facilities are so primitive in this department that two young faculty have lost much time trying to set up laboratories that will sustain their competitiveness.

Our departments of Microbiology and Public Health, Anatomy and Physiology are in obsolete buildings handicapping both the quality of research and the size of the graduate student and postdoctoral enrollments we can accommodate.

NEW YORK UNIVERSITY

In our Biology Department, a number of research efforts are hampered by inadequate facilities. In some areas of biological research, investigations are hampered by the lack of up-to-date central facilities, including a DNA sequencer and synthesis facility, and a spectro-fluorimeter. In plant molecular biology and plant systematic biology, greenhouses are an essential facility; in the absence of a modern greenhouse, our biology investigators are unable to pursue research in this area.

UNIVERSITY OF CALIFORNIA

Less than 50% of the available research space is "suitable for use in the most highly developed and scientifically sophisticated research in its field," according to input provided by S/E units. Research is most upgraded with institutional funds in connection with recruitment and retention of faculty. Little upgrading can be accomplished through research grant funding. We need augmented funding levels to expand our program of renovations to include the utility and service infrastructure within buildings. One of our middle-size bioscience units (not included in the three-phase bioscience space upgrading) has described the departmental situation as follows:

Controlled Temperature and Clean Air In Laboratories (Highest Priority)

Controlled temperature in our laboratories is now even more important than in the past. Modern research instruments such as our recently acquired Fourier-transform infrared (FTIR) and inductively coupled plasma (ICP) spectrographs require environments with very limited temperature range to perform optimally. Although air conditioning is rarely needed for comfort in Berkeley, these instruments with their highly precise optical systems and associated computers do require it. Studies of soil water transport, water extraction, measurement of soil water potential, soil rheology and soil microbiology all require controlled temperature environments. The department presently has only one very small constant temperature room to accommodate these activities, and this facility has a history of being inoperative for very long periods (over 1 year in one episode), apparently because of the difficulty in obtaining parts for an obsolete system.

The air blown into labs and offices by the Hilgard ventilation system is extremely dirty. Improvised filters put over outlets are inefficient expedients. They are overloaded with particles in a short time. The fiberglass filter over the air outlet above the computer where I am now sitting has reached "breakthrough" in less than four weeks.

Fume Hoods with Acid Traps (Very high priority)

Digestion of soil and plant materials requires strong reagents and high temperature. At present there is only one hood in the department with a perchloric acid trap and which is equipped with scrubbers to remove nitric acid fumes. The provisions for trapping the potentially explosive perchloric acid and corrosive nitric acid fumes were improvised with department resources. While this one arrangement is effective, it is clearly inadequate for the department's needs. All department laboratories doing wet chemistry should have hoods with acid filters/traps for safety, environmental protection and preservation of the ducts.

UNIVERSITY OF CALIFORNIA - LOS ANGELES

Studies in basic and applied molecular biology in relationship to developments in biotechnology are being impaired by the lack of modern facilities. Such facilities require special fermentation facilities, special environmentally controlled areas and the modern laboratory systems that meet the regulatory requirements that have been recently promulgated in this area.

THE UNIVERSITY OF IOWA

Outdated facilities are impacting adversely on the University of Iowa's undergraduate and graduate education programs. For example, in biology, as intensive laboratory training in molecular techniques is required for large numbers of undergraduate students, classroom laboratory space once used only for desktop experiments must be remodeled and rewired to handle multiple centrifuges, power packs, refrigerators, personal computers, tissue culture and chemical hoods. The problem is repeated in each of the University's science and engineering departments for which a myriad of automated and electronic equipment is essential for basic undergraduate laboratory instruction.

The eventual proof of the biologic process is the living animal. As our knowledge increase, so the effects of the various agents and insults are becoming clearer and the demand for clean, pathogen-free animal space is increasing. Added to this is the provision for transgenic animals, in which the ultimate test of the new DNA-technology is conducted.

Researchers in our biomedical area, particularly in our internationally renowned cardiovascular research center, must presently delay or forgo studies utilizing dogs and primates because of the current limited capacity of existing facilities. Proposed U.S. Department of Agriculture regulations will require a doubling of space for housing and exercise of dogs and primates. In addition, there is a critical need to develop special facilities for the use of transgenic mice, containment of pregnant sheep, and improved and expanded aseptic surgical research facilities. These are all examples of the important needs to improve the infrastructure for health related studies. It is estimated that the University of Iowa will need to invest $6.4 million in improvement and expansion of animal facilities to comply with regulations and to meet the expanding biomedical research needs. This investment is in addition to $6 million that has been spent by the University since 1979 to bring the University into compliance with USDA regulations and PHS guidelines.

UNIVERSITY OF MARYLAND

On our campus, some of the buildings have air conditioning powered by steam; this arrangement results in shut-downs for the cleaning of the equipment and in outages, when power is interrupted. This antiquated set-up adversely affects research endeavors in biochemistry and in the animal sciences.

Our microbiology program was housed for years in an antiquated building with make-shift arrangements for new research requirements. Clearly, the inadequacy of the facilities prevented the department from beginning serious work in certain new biotechnology areas.

UNIVERSITY OF MINNESOTA

Antiquated animal research facilities are blocking research using appropriate animal models in biomedical fields, in modern work on livestock production, and in investigations of certain animal diseases in veterinary medicine. Moreover, in the biological sciences, work on the genetic engineering of fish and other aspects of basic fish biology is impeded by lack of good space to rear and maintain the fish. Recently some makeshift facilities malfunctioned and we lost some very important specimens, setting back our work significantly. Also in the biological and agricultural sciences, greenhouse space for basic studies in plants is completely inadequate. Two of our "research" greenhouses are deteriorated so badly that they cannot be renovated; we are critically concerned that this not be allowed to happen to the others which now badly need renovation. Our plant sciences research is greatly impeded by this problem. Often the next logical experiment simply cannot be done due to lack of facilities.

In many of our research programs in psychology, in the social sciences, in the biological sciences, the physical sciences, and in the biomedical sciences we have had to resort to renting space in the community. This allows us to acquire space that is adequate to support the research function, but it impedes the development of the research program because it isolates people from others with whom they should be interacting. This has become a critical problem for us in some programs.

UNIVERSITY OF PITTSBURGH

Obsolete X-ray crystallography facilities and equipment in our Departments of Biological Sciences and Crystallography, and in our medical school's basic science departments constrain and impede various research projects on protein structure being conducted at our University.

Our Departments of Biological Sciences and Behavioral Neuroscience are in need of a central animal housing facility and state-of-the-art tissue laboratories in order better to capitalize on the talents of their faculties and graduate students.

UNIVERSITY OF SOUTHERN CALIFORNIA

All of the Department of Biological Sciences portions of Geological Sciences and Chemistry are housed in the buildings listed above and the research and educational programs offered by these departments is being adversely affected by the inadequate and/or obsolete facilities. A few examples:

In Marine Biology we are trying to expand an exciting research effort which combines biochemical, microbiological and molecular techniques in the study of the early developmental stages of invertebrate organisms. In addition to basic science, the work has significant application in biotechnology and agriculture. However, the research is being severely hampered by obsolete facilities. All of the laboratory bench-tops are coated wood and unusable or incompatible with the use of chemicals, stains, and radioisotope tracers routinely used by the faculty and graduate students. (Chemical hoods in the building no longer meet code requirements for many acids are highly volatile or toxic substances.) The laboratories are not air-conditioned and become unbearably warm in summer months, to the inconvenience of researchers and the detriment of computers and electronics. Expansion of the program can only be done as labs in the building are renovated at considerable time and expense. The Molecular Biology program is housed in buildings now more than 25 years old and in need of extensive renovation of the hood ducting, air supply system, benching and countertops (which contain an asbestos impregnated epoxy) and laboratory layout. The lack of adequate laboratory facilities is adversely affecting the development of this very important component of the Biological Sciences. Without well-equipped, modern facilities, the Section is at a disadvantage in the recruitment of both junior and senior level faculty. The program has critical deficiencies in the areas of molecular, cellular and developmental biology, and we are trying to fill this need by building research efforts in gene control during development, cellular growth controls and communication between cells and signal transduction. However, these efforts are limited by the poor quality of the existing research space and, again, extensive renovation must occur before we can proceed.

THE UNIVERSITY OF TEXAS AT AUSTIN

Molecular Biology: Life sciences at UT reside in the traditional departments of Botany, Microbiology, and Zoology and in the Divisions of Biochemistry and Nutrition. The life sciences, biochemistry, and nutrition groups have, over the past 10 years, attempted to develop programs in molecular biology. The major problem has been recruiting new faculty in the absence of modern facilities to support molecular biology research. The Department of Botany, with a #1 ranking nationally, is housed in a building constructed in 1932, and the Department of Microbiology and approximately half of the faculty in the Division of Biochemistry are housed in a building constructed in 1954. The Division of Nutrition is housed in a building that does not have the support facilities for modern wet-bench research. The Botany building does not have the support facilities for modern research, nor is it feasible to renovate the building to conduct modern molecular biology research. The building that houses the Department of Microbiology and some of the biochemists can be renovated to support molecular biology research; however, the estimated cost for renovation is $16 million. The Department of Zoology (ranked #7 nationally) is housed in a building constructed in 1968. Although this building is suitable for molecular biology research, there is need for substantial renovation for existing faculty as well as for new faculty.

Molecular biology development at UT has the highest priority. Approximately $65-$75 million is required to construct new facilities for molecular biology and to renovate existing buildings for life sciences and biochemistry. Current plans are to construct a new molecular biology building at an estimated cost of $25 million; however, this will not address the renovation needs of the existing life science departments and the Division of Biochemistry. The consequences of obsolete space for the life sciences are that the nationally ranked programs will decline in quality; faculty will leave and recruitment of the best faculty will not be possible.

Many scientists on our campus have the capacity to contribute to the human genome project but lack the necessary equipment, modern laboratory facilities, and automated instruments (such as an automated DNA sequencer and robotics) to compete successfully with other laboratories in the world.

The revolution created by recent developments in molecular biology will permanently change biology, agriculture, and medicine. Given our lack of state-of-the-art molecular biology research facilities, however, we are not in a position at the present time to be a major research force in this field. Other universities are in similar circumstances, making our overall national effort weaker than many existing programs in Japan and Europe.

YALE UNIVERSITY

Deteriorating and obsolete greenhouses inhibit ongoing research in plant molecular biology, an investigation important to our understanding of plant genetics as well as to advances in practical agriculture.

In cell biology, an imperfectly functioning temperature control ended a fifteen-year-old experiment by destroying a genetic stock collection of fruit flies. Although valuable results had been obtained from the experiment, its premature termination required additional expenditures and a three-year delay to partially replicate lost materials.

Chemistry

CARNEGIE MELLON UNIVERSITY

The major place in which we have had an adverse effect is in the teaching of chemistry. We have a brilliant new idea for education that will increase the number of majors in both high school and college for chemistry. Unfortunately, in order to implement our ideas, we need a modern facility. We also have some original ideas on ways in which new laboratories should be constructed. We are trying to raise $7 million to proceed with this project. In the meantime, the idea is languishing, and we are not doing as good a job as we could for the education of chemists.

The chemical industry is worrying about the future supply of chemists, because this area is no longer drawing the numbers of students at either the undergraduate or graduate level that are needed by the industry. Obviously, this industry remains an important one for the United States.

CASE WESTERN UNIVERSITY

In the area of polymers, laboratory facilities for structural analysis do not require heavy wet chemistry facilities and related mechanical support systems. Cutting edge research in this area has now moved to synthesis and/or creation of polymers such that new wet chemistry facilities are required. Provided for increased air changes in a new laboratory located in a 1950's building, with limited mechanical capabilities, is very difficult. Achieving full research activity potential and maintaining safe environmental conditions and also very difficult.

THE CATHOLIC UNIVERSITY OF AMERICA

The overall chemistry program will require two large pieces of equipment to determine structure of complex and molecules: a hi-field NMR spectrometer for work in Biochemistry and a hi-resolution mass spectrometer for research in Organic chemistry. It will be impossible for CUA to compete in research involving molecular structure without these equipments. Each system will cost at least $500,000. CUA does not have the ability to purchase large equipment in this price range, nor is it in a position to do so even if a 50%-50% cost sharing is required.

COLORADO STATE UNIVERSITY

The Chemistry Building is an example of the pending needs on this campus. Storage space for chemicals and supplies is grossly inadequate. Supplies are stored in cabinets in hallways, thus exposing students and faculty to potential problems. Disposal of chemicals is borderline at best, according to current standards. Equipment in many cases has been given the "bandaid" fix, and requires daily tinkering to keep it operational. Library and study space in the building are grossly inadequate; classrooms are overcrowded.

Another negative effect of the facilities problem in the Department of Chemistry is the University's ability to retain outstanding faculty and attract reputable new faculty. In both retention and hiring situations, we are told by the faculty that we would fare better in this competitive arena if better facilities existed. Typically, we can cope with the salary demands of the faculty. It is the need for facility upgrade and/or replacement that is most difficult to accommodate.

IOWA STATE UNIVERSITY

At Iowa State University we do have programs that are severely affected by obsolete research facilities. In chemistry, traditionally one of the strongest programs at Iowa State University, we are in the midst of a major renovation project of our core chemistry facility. Our present facility of more than 200,000 square feet houses more than 30 chemistry research groups. Unfortunately, our chemistry research groups are concentrated in areas of traditional strength at Iowa State (materials, sciences, organic chemistry, etc.) and because they occupy all present space we are limited in our ability to grow chemistry research activities into new areas where interdisciplinary research is required. For instance, we have a strong interest in developing a natural systems chemistry program that will support and enhance our movement into fundamental agricultural research. To do this we need facilities and equipment on a relatively major scale. We are unable to provide such facilities or equipment, in spite of massive state investment, and as a result we feel that certain new knowledge producing environments will not be created, and as a result certain critical knowledge may not come about. It's important to remember that it's not as if we can eliminate our existing chemistry program, which is successful both in terms of research and in terms of teaching, to move into new areas because we cannot. We have developed ongoing streams of knowledge and student production that justify their continuation. But now to move into broader and more interdisciplinary programs linking chemistry with other activities on the campus we find that we are severely facilities and equipment limited. In our opinion this does result in an impedance of the research enterprise.

THE JOHNS HOPKINS UNIVERSITY

Molecular and atomic chemistry research at Hopkins is hampered by lack of adequate facilities to house modern equipment, such as state-of-the art NMR and X-ray diffraction instruments. This situation is compounded by the difficulties in computer/information networks and similar systems. This adversely affects research involving, for example, DNA chemistry, polymers, and advanced materials, each of which is a critical area of technology for the nation.

UNIVERSITY OF PITTSBURGH

Very recently, one of our senior organic chemists who pioneered the field of molecular recognition, a field of widespread interest and application, left the University for another institution because we were unable to provide him with adequate research facilities and state-of-the-art equipment needed to establish an Institute for Molecular Recognition.

UNIVERSITY OF ROCHESTER

Funding was recently received for an NSF Science and Technology Center in Chemistry: in order to house the Center, major renovation, $900,000 of costs, must be done in an existing building. Only $250,000 of that cost was funded by the grant; the institution must bear the rest of the cost.

UNIVERSITY OF SOUTHERN CALIFORNIA

There are a number of exciting new research opportunities in organic and organic-metallic chemistry which the faculty of Chemistry would like to exploit but find themselves handicapped by the aging and inadequate laboratory facilities available. Although a few of the laboratories have recently been improved, the majority of the hoods, ducting and air supply system is substandard and in some cases no longer meets code requirements. The problems related to laboratory facilities are not only restricting the expansion of existing research programs, they are increasingly becoming a major hindrance in the recruitment of replacement and new faculty. At the present time we are losing one junior professor because of problems related to the research space.

UNIVERSITY OF TEXAS AT AUSTIN

Some of our programs in organic, inorganic, and physical chemistry are being impeded because of the facilities in which they are being conducted. The laboratories were constructed in the early 1960s and are not equipped and configured to support modern research in these areas. Their renovation is sorely needed to address issues of safety and research productivity. For example, some experimentation currently must be moved to a different area of the building where hoods and other laboratory facilities can support the work to be done. This is particularly true of materials science research in which highly toxic and dangerous materials are under investigation.

UNIVERSITY OF WASHINGTON

In January 1988 the University of Washington retained two prestigious architectural firms, the NBBJ Group and TRA Associates, to study its science and engineering facilities. Among the conclusions reported by this study are the following:

The need for additional space for science and engineering at the University of Washington in the next 15 years totals 527,000 assignable square ft. (ASF) under a "no growth scenario", or 867,000 ASF under a "modest growth scenario". These numbers correspond to an increase of 32% and 52%, respectively.

The physics building was described as follows: "Physics Hall, built in 1928, is the main physics laboratory and teaching facility at the University of Washington. It is unfit for the conduct of modern science. It lacks the capability to accommodate heavy equipment in laboratories and would require major structural improvements to handle additional floor loads and meet seismic standards. Other problems pose threat to the safety of its occupants; unenclosed exit stairs would act as chimneys in event of a fire; adequate electrical power is not available in many laboratories; and some labs illegally vent into corridors." Bagley Hall, the building which houses the Department of Chemistry, is, in general, in worse condition than the physics building.

Engineering

BROWN UNIVERSITY

Our engineering and physics building is over 20 years old and can not accommodate any expansions into new topical area, e.g. thin films, robotics, and laser applications.

THE CATHOLIC UNIVERSITY OF AMERICA

In the School of Engineering, it is desired to expand a strong and well-supported program in underwater acoustics by the U.S. Navy to a much needed area of architectural acoustics. The present sponsor is not interested in this expansion and the University is in no position to provide the one million dollars necessary to provided the equipment to initiate the program. Were the facilities developed, there is no doubt that it would attract ready sponsorship. Similarly, modest programs in robotics and active control of structures can only be fully developed with the infusion of equipment monies of similar magnitude.

CORNELL UNIVERSITY

An example of a major program at Cornell University which is adversely affected by obsolete research laboratories is the School of Electrical Engineering. This school occupies a building which was built in the mid-1950's in order to house a planned, much larger program in undergraduate education. The planning did not include any element of research facilities. Over the past 30 years the School of Engineering has evolved into one of the leading research departments in its field in the United States. The research function, including office space for graduate students, postdoctorals, research associates, shops and research laboratories was shoe-horned into the existing building, or, in some cases, laboratories were placed in off-campus locations or in other buildings. As research and instructional pressures mounted due to the increased student interest in electrical engineering, space devoted to instruction shrank. One consequence was the reduction of the required junior-year laboratory course from five hours per week in the laboratory to three hours per week. This allowed twice as many laboratory sections to be taught. Instructional material was taken out of the course in order to complete it in three hours instead of the five previous. Subsequently, the two-semester sequence was reduced to a single semester and additional teaching laboratories which were used for specialized senior-level courses were merged or eliminated. The research laboratories, being placed in former classrooms, instructional laboratories, offices, and so forth are totally inadequate. They generally have no humidity control, no air conditioning, and so forth, which makes use of electronic equipment difficult on hot days. Research space per faculty member in the school is less than 500 square feet, and compared to about 2000 square feet in comparable departments. As a consequence, the magnitude and quality of research and the quality of undergraduate instruction which is done in this school, an area vital to national competitiveness, is severely limited by inadequate space.

As a consequence of this situation and similar pressures in other departments in the engineering college, the college prepared a master plan for meeting space needs. The first element of this master plan was to have been construction of a laboratory building for the School of Electrical Engineering. Because of immediate time pressures to house the new supercomputing facility, the college's space needs were placed second in priority. Even though the college master plan was created three years ago, it now appears that it will be at least five to ten years before resources can be found to begin construction on a laboratory building for electrical engineering. In this school, the space pressures on both teaching and research will therefore have spanned the entire professional careers of a generation of faculty members.

A third area of need is closely related to the microelectronics area of the School of Electrical Engineering. The university is currently trying to organize joint university/corporation efforts for research on optoelectronics, electronic packaging, production of semiconductor devices, and advanced lithography. Those strategic liaisons with corporations envision environment which will contain both open research by university people and collaborative research conducted by employees of several different corporations. Corporations might also be able to rent space in an adjacent facility to do their own proprietary work. In this particular case, it may be feasible to pay for the needed space by the program revenues, although it will be a substantial challenge to provide this space on the required time schedule (about 18 months). If we are unable to provide this space, the chance for major industrial collaborations which could affect the national competitive picture in these important areas will be severely compromised.

MICHIGAN STATE UNIVERSITY

In engineering we have been so short of laboratory space we were unable to recruit faculty with active research programs. We purchased a commercial facility several miles from the campus and adapted it to serve as a turbulence laboratory. We built a temporary structure of 66,000 square feet about one mile from the Engineering Building in which to develop laboratories and finally we have received state bonding funds to double the size of the present Engineering Building. When this addition is completed in late fall of 1989 we will begin renovation of the old wing. This should be completed in 1991, but the total facility will not provide all the Engineering departments with research space needed.

MISSISSIPPI STATE UNIVERSITY

Aerospace Engineering - education programs are adversely affected because of restricted instructional laboratories, lack of faculty office's, and inadequate air conditioning resulting in excessive computer down-time. The problem of asbestos removal must be addressed (this is true for many buildings, instructional, research, and administration - across campus). Some research, faculty, and instructional space will become available when new construction is completed in the Research Park complex; however, this space cannot be effectively utilized unless and until a fully working computer networking system is in place.

The department's Raspet Flight Laboratory, located some miles away from the campus, was built in the early 60's. Continuing renovation is required to keep this aging facility operative. As the university's aerospace research programs increase, the available space in the nearly 40-year old facility becomes more cramped and less efficient.

The Diagnostic Instrumentation Analysis Laboratory (DIAL) develops advanced optical instrumentation systems for use in fossil energy technologies and in manufacturing and industrial processes. Its laboratories are scattered through four buildings, necessitating dismantling of equipment in one laboratory, transport to the test stand facility, and reassembly for testing. The process then must be repeated to return the instrumentation to the developmental laboratory. DIAL research interests included the development of intrusive probes and sensors for diagnostic use in MHD or similar facilities, and extension of the capabilities of the Laser Doppler Velocimeter System (which measures particle velocity along a plane) and development of a 3-D system. Such extension of research requires additional appropriate space in a research facility designed for this type of research.

RUTGERS UNIVERSITY

[E]ngineering research and graduate education at Rutgers have only recently received strong State support. They are developing rapidly in response to imperative regional needs, exploiting evident opportunities created by the exceptional quality of corporate engineering research. Availability of departmental research facilities determines the pace at which these developments can proceed.

UNIVERSITY OF BUFFALO:

In all areas of engineering, including materials, manufacturing engineering, biomedical and biochemical engineering, and engineering instruction, new technology is developing so rapidly that it is impossible for the Engineering School to have available the latest hardware and, in the cases where computing is part of the program, the latest software.

As a specific example, the materials research programs offered through our Departments of Chemical, Electrical, and Mechanical Engineering face the following:

Our high resolution microscopy and analytical facilities, which must support the materials efforts, are wholly inadequate. We have faculty with the talent but our research laboratories are either without the appropriate equipment (clean rooms, furnaces, CVD facilities, MBE, microscopes, etc.) or have an inadequate, technologically obsolete capability.

UNIVERSITY OF FLORIDA

An accurate estimate of the need for space to feed the department's rapid growth in research is thirty thousand square feet. There are many good reasons for this additional need for space, but the most compelling is that the department has hired ten new faculty in the last eighteen months, among them the college's first Eminent Scholar, Dr. Tang Sah. Dr. Sah occupies the Robert C. Pittman endowed chair. He is a leading researcher in semiconductor electronics. In the 1950's he worked with William Shockley, Nobel Laureate and co-inventor of the transistor, as a senior member of the technical staff of the Shockley Transistor Corp. In 1959, Sah became head of the physics department at Fairchild Semiconductor Corp., leading a group that developed the first stable MOS transistors. His work pioneered the technology that made possible the first digital watches. He continues to make major contributions as is evident by his receiving the Jack Morton Award from IEEE this year. We have attracted Dr. Sah to the University, but are now unable to meet his space needs. His group alone will secure over $1,250,000 in research funding next year. The work is largely experimental and requires significant amounts of high-quality (like clean rooms) space. To quote Dr. Sah's closest colleague, Dr. Fred Lindholm:

"1. We cannot get the experimental stations set up in which to do our research.
2. We cannot add the graduate students coming this fall who need to use these work stations.
3. We cannot add postdocs we need to help us do this research and to assist in educating our graduate students.
4. We cannot have the use of Professor Sah's reprint files or his journals.

Accordingly, our research and education via research is severely compromised, and our ability to bring in substantive research funding to provide for graduate student education and the maturation of our junior faculty associates is severely limited."

This is not a new problem. After being with us for less than eighteen months, Dr. Luis Figueroa, a well-known expert in laser technology, resigned in June of 1987 because of inadequate facilities. In his letter of resignation he states, "When I was hired, I naively assumed I would get space to build a semiconductor laser characterization lab to support my research. I was mistaken! If I would have known about the magnitude of the space crisis before I was hired, I would have either negotiated using different methods or found a better arrangement elsewhere."

UNIVERSITY OF ILLINOIS

In Mechanical Engineering the space is very open and not usable for modern instrumentation. It has been necessary to divide up floor space with wire cages and put laser equipment inside the caged areas. The lasers are used in the diagnostics of combustion and fluid flows. There is no computer control of the engines. The control devised were built in the 20's and 30's.

In wind-tunnel-like experiments, there is a need to go to three dimensional studies and to scale up devices by 400-800%. This would require large-capacity vacuum and high-pressure air sources, which are not available.

A proposed center for the study of refrigeration that involves industry-university cooperation lacks the space and environmental controls to conduct the studies properly. A major activity involves the replacement of CFCs, and the substitute materials are so exotic that leak detection is difficult and there are no known sealing materials. Tribology studies with these materials are needed but there are no facilities in which to conduct these studies.

Across the engineering departments in general, only 29% of the research space is considered suitable for use in the most highly developed and scientifically sophisticated research in the field. In the physical sciences this number is higher (49%), but in the environmental sciences the corresponding percentage is only 8%.

UNIVERSITY OF PITTSBURGH

X-ray diffraction facilities and equipment in the Department of Materials Science and Engineering are 15 - 20 years old, and thus state-of-the-art research on polymers just cannot be done using them; our faculty who need state-of-the-art X-ray diffraction facilities and equipment must go elsewhere to do their X-ray diffraction work.

Moreover, due to inadequate space and lack of equipment, our School of Engineering is unable to establish a cell biology laboratory that is needed for the School's developing research and graduate training program in bioengineering.

The building that houses our School of Engineering was designed in the late 1960s and completed in 1972. At that time, the building's air conditioning was adequate relative to needs, but its air conditioning is today inadequate relative to current needs. As a consequence, each time a new laboratory is set up, a separate air conditioning system must be added at a cost of approximately $20,000. The cost to upgrade the building's central system is approximately $350,000 to $400,000. Obviously, given finite University and School of Engineering resources, funds used for air conditioning additions or upgrades cannot then be otherwise used in support of the Schools' research, training, and service activities.

UNIVERSITY OF SOUTHERN CALIFORNIA

Photonics/Optical Computing research is greatly hampered by the lack of adequate laboratory space. The materials processing side in particular requires very extensive (and expensive) facilities. This is an extremely important new technology that could lead to the so-called "sixth generation" computers.

We have millions of dollars of government research support including a U.R.I. in this area, and have one of the top two or three research groups in the country. The potential impact of their research and the necessary technology transfer will be compromised if new facilities are not created.

Manufacturing is another vastly under spaced and under-equipped area. We have major government and industry support through our Institute for Manufacturing and Automation Research (IMAR), but no real facility in which to conduct meaningful research.

The Division of Natural Science and Mathematics occupies five buildings in which the laboratory research facilities are obsolete or substandard, and a sixth in which the facilities are marginal. Only two buildings in the Sciences have adequate research facilities. The worst cases are buildings more than 50 years old, in which there are acute problems with the electrical services, hoods and venting system, plumbing, benching, heating and air conditioning systems and general design of the laboratories. To varying degrees, all of the subpart buildings share these problems.

UNIVERSITY OF TEXAS-AUSTIN

The Department of Aerospace Engineering and Engineering Mechanics research and education programs in guidance and control are affected by the inability of the guidance and control group to pursue a broad range of research activities because of the nonexistence of a controls research laboratory facility. Two areas of fundamental research for the future are fault-tolerant flight control systems and the development of new and sophisticated sensors and actuators. While our current research is primarily analytical and computational in nature, our capabilities would be greatly enhanced by including hardware in our future research activities.

Both of the research areas mentioned above are considered of primary importance to the future of U.S. aerospace industries. In addition, our students would be more effective in these developments if they had a better understanding of computers, sensors, and actuators and their use in sophisticated flight control systems.

The Department of Aerospace engineering and Engineering Mechanics has no facilities for high temperature work on metals, metal matrix composites and ceramics, nor does it have adequate facilities for the study of fiber/epoxy types of composites. It has no facilities for evaluating the mechanical characteristics of brittle materials such as ceramics.

The internationally recognized Structural Engineering Laboratory research and teaching program is threatened by an aging physical plant and facilities that are not adequate to support current or anticipated research efforts. For example, a 25-ton overhead crane has hazardous exposed electrical rails, worn-out brakes, antiquated controls, and other safety problems, the original electrical distribution system unsatisfactory, providing insufficient electrical power for equipment now in the lab and on order; roof and wall problems, rainwater, dust, and temperature changes endanger equipment and research projects, rotting, damaged, and worn-out doors provide no security; there is insufficient air conditioned laboratory equipment; and there is an acute shortage of faculty, staff, and student office and work space.

UNIVERSITY OF VIRGINIA

Externally funded research at the University of Virginia is growing currently at an annual rate of 15%. Such growth cannot continue because we have already saturated our research space.

In the School of Engineering and Applied Science, a major grant from the Department of Transportation supporting experimental crash impact research is being severely impeded by the unavailability of suitable research space. In addition, the space available for the support of academic computing is ridiculously inadequate.

VANDERBILT UNIVERSITY

Vanderbilt currently has sufficient space for most work, with the exception of our Engineering School. One recent inventory shows that the Engineering School needs over 67,000 net assignable square feet - 57,440 of which is need R&D space. This shortage is critical, as illustrated by the case of laser equipment on campus: because of space constraints, the Engineering School has unused lasers in storage and the Physics Department has underused lasers – all this after construction of a $2.6 M building for a free electron laser.

YALE UNIVERSITY

In chemical engineering, a faulty air handling system permitted humidity to build up and destroy a salt crystal operating as the beam splitter of an interferometer, causing research delays and several thousand dollars in additional costs to Yale.

Environmental Sciences

COLORADO STATE UNIVERSITY

The Natural Resource Ecology Laboratory represents an area of keen national and international interest. The lack of adequate space is acute in this department. Refrigerators sit in hallways. Students sit at chairs in hallways to study (very distracting and undesirable situation). This department has experienced extreme difficulty in retaining outstanding researchers due to the lack of adequate facilities and space.

These two departments are representative of the harm that can be caused to the quality of programs as the result of sub-par facilities. As stated previously, it is not only the quality of the research that suffers, but the quality of the educational programs as well.

CORNELL UNIVERSITY

Another example on the Cornell campus is the Center for Environmental Research. The staff of this center are currently dispersed among four different buildings on the campus. Substantial recent effort in this center has focused on questions related to global environmental change. There appear to be major opportunities for more interdisciplinary basic research to be conducted in this area, and funding for programs in the center has grown substantially over the past two or three years. This center needs about 15,000 square feet to consolidate its central operations in one place and provide a focus for expanding efforts on the global environment. The space needs include both offices and laboratories. No solution is on the horizon for meeting those space needs, even though a substantial fraction of the work of this center is in the statutory colleges of the university that are supported by the State of New York. Budget difficulties in the state, coupled with pressures for better teaching space in the biological sciences, make it unlikely that the state will be able to respond to such space needs for a period on the order of five years. Even though basic interdisciplinary research on global environmental effects is of vital importance to society, it is unlikely that programs of the required magnitude can be mounted within the space constraints of the institution. Graduate students will not be trained in sufficient numbers to meet national needs in the environmental area as a result of current shortfalls in research space.

UNIVERSITY OF KANSAS

Recently, society has begun to recognize that an ecological crisis exists. Species are being depleted at an enormous rate, especially in the American tropics. This realization is recent, even though professionals have been warning of the crisis for decades. The University of Kansas is one of a few universities that has maintained a concentration of talent in the area of natural history. We are moving, with similar institutions, to establish a program to inventory species diversity in threatened areas. Our efforts will be severely handicapped because we do not have adequate facilities for storage, analysis and curation of materials that will be obtained during these studies. We will have to solve this space problem before we can move forward.

UNIVERSITY OF WISCONSIN-MILWAUKEE

While some facilities modernization has occurred at the Center for Great Lakes Studies (due in large part to an extramural award of $500K which leveraged an additional $3 million), much more must be done to replace obsolete research instrumentation which is employed across various areas of research (aquatic, environmental science, engineering and in other disciplines). The Center is the major research facility on the Great Lakes and has the potential, with proper development, to work on the major problems of environmental health facing the Midwest and the nation.

Materials Sciences

CARNEGIE MELLON UNIVERSITY

In the research area, there is a major shortage of space for the accomplishment of large-scale research in areas such as robotics and advanced materials. We have been renovating a number of buildings, but we are still short of the space that we need. We have a series of original ideas on the handling of nuclear cleanups, and we need more space for constructing the robots that will be able to move into a nuclear plant or other hazardous areas to eliminate the risk to human beings. We are trying to find money and space to do this. In the meantime, the research is being held back. Similarly, research in electronic and other non-metallic materials is limited by space and equipment. We have a major national problem, and progress is being impeded by the lack of facilities. We are in grave danger of being unable to compete in the international arena in electronics and advanced materials.

STANFORD UNIVERSITY

Modern materials research involves building materials atom layer by atom layer. This work cannot be expanded because of the lack of a building to house the special equipment. Such equipment requires special facilities providing adequate vibration isolation and systems to handle the wide range of gases and liquids, some with highly hazardous or with unknown properties used in atomic-level artificially structured materials. The materials affected include high-temperature superconductors, high-speed transistors, new advanced lasers, and new lithographic techniques.

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

Advanced Electronic Materials Processing program is not advancing as rapidly as it could if adequate space were available. If legislative funding for new space, which has been requested, is not forthcoming, this nationally competitive program may be in jeopardy.

UNIVERSITY OF PITTSBURGH

Inadequate research facilities and insufficient numbers of available scanning tunneling electron microscopes and ion microscopes, and the lack of a tandem accelerator for thin-film analysis are impeding our research and graduate programs in surface science and materials science and engineering.

UNIVERSITY OF TEXAS -AUSTIN

High-temperature materials in general, ceramics, and lightweight non-metal composite represent the way of the future in aeronautical, space, deep water, automotive, and energy production areas. Without substantial investment in suitable facilities and equipment for evaluating the mechanical behavior of materials for transfer to these applications, the State will not be able to compete in national or international arenas. This will definitely have adverse economic repercussions.

In microelectronics research, currently does not have the clean room facilities required for fabrication of small-geometry device structures. Our lithography equipment is inadequate for features below one micron. Moreover, we do not have adequate toxic gas handling facilities and safety equipment necessary for many semiconductor growth and processing requirements.

Physics

MICHIGAN STATE UNIVERSITY

Our Department of Physics, except for the nuclear physicists who use the new National Superconducting Cyclotron Laboratory, are very poorly housed and severely constrained in spite of the fact that solid-state physics is a key contributor to a state of Michigan priority area of material science.

UNIVERSITY OF CALIFORNIA - LOS ANGELES

Studies in high-energy and plasma physics are being impaired by the lack of high bay spaces and the infrastructure components (electrical and plumbing) required for medium and large-scale experiments. Facilities for such mesoscale experiments are becoming essential for advances in the physical sciences and engineering.

UNIVERSITY OF FLORIDA

Approximately two years ago the Department of Physics at the University of Florida decided not to recruit anyone with a speciality in experimental physics. All available lab space had been exhausted. Therefore, only theoretical physicists were recruited. Basically, experimental physics has come to a halt unless new space becomes available.

UNIVERSITY OF PITTSBURGH

Our Department of Physics and Astronomy is developing a program in condensed matter physics, but this effort is being severely hampered by deteriorated research facilities and obsolete equipment, deficiencies which cannot be remedied by the University due to budget constraints.

UNIVERSITY OF ROCHESTER:

The University's Laboratory for Laser Energetics will have a $40 million program to upgrade its high-power laser. Brick and mortar money is not available for the extensive modifications required for the new target chamber building. This unique national facility will be a "go-no go" kind of decision based on whether the University provides the building. Do we fund it from tuition? No! Do we fund it from endowment? No! Do we borrow at market rates (not tax-exempted bonds, for we are at the cap limitation) and pay back the funds on the government-allowed amortization basis? Not likely to find a 50-year loan! Do we fund from gifts? No, cannot get a private gift for government research. Will the State pay for the building? Doubtful! How do we fund this important research?

THE UNIVERSITY OF TEXAS AT AUSTIN

In the Department of Physics obsolete research equipment has adversely affected departmental teaching and research. For example, in order to machine large-flow chambers to the required precision, sophisticated machine tools are required. Yet, all of our large bed millers and vertical lathes are over 40 years old. Newer equipment which is numerically controlled would allow construction of chambers to study the onset of turbulence in large systems, but this research initiative has not been possible. As a second example, the current materials preparation facility in the Department of Physics contains preparation equipment and test equipment which is over 20 years old. Because of a lack of user facilities, our department was unable to pursue a research program in the study of the new superconducting materials. In addition, the lack of a new modern research facility for the study of ultra-small microelectronic structures has precluded possible participation by our Department of Physics in several joint university/industry research projects.

UNIVERSITY OF VIRGINIA

Externally funded research at the University of Virginia is growing currently at an annual rate of 15%. Such growth cannot be continued because we have already saturated our research space. In the College of Arts and Sciences, a group of approximately 6 research faculty in nuclear and high energy physics who generate more than $3M/year in external research support have nowhere to put the equipment which has been purchased with federal funds.

UNIVERSITY OF WASHINGTON:

In January 1988 the University of Washington retained two prestigious architectural firms, the NBBJ Group and TRA Associates, to study its science and engineering facilities. Among the conclusions reported by this study are the following:

The need for additional space for science and engineering at the University of Washington in the next 15 years totals 527,000 assignable square ft. (ASF) under a "no growth scenario" or 867,000 ASF under a "modest growth scenario." These numbers correspond to an increase of 32% and 52% respectively.

The physics building was described as follows: "Physics Hall, built in 1928, is the main physics laboratory and teaching facility at the University of Washington. It is unfit for the conduct of modern science. It lacks the capability to accommodate heavy equipment in laboratories and would require major structural improvements to handle additional floor loads and meet seismic standards. Other problems pose threats to the safety of its occupants; unenclosed exit stairs would act as chimneys in event of fire; adequate electrical power is not available in many laboratories; and some labs illegally vent into corridors." Bagley Hall, the building which houses the Department of Chemistry, is, in general, in worse condition than the physics building.

YALE UNIVERSITY

In physics, difficulties in maintaining the water impermeability of the envelope of a specific research building, has caused constant adjustment and realignment of equipment, creating both delays and frustration.

Mr. **Boucher**. Thank you, Dr. Wyatt. We will withhold questions until all the panelists have presented their oral statements.

Dr. Johnson, we will be glad to hear from you.

STATEMENT OF DR. ALBERT W. JOHNSON, VICE PRESIDENT FOR ACADEMIC AFFAIRS, SAN DIEGO STATE UNIVERSITY, SAN DIEGO, CALIFORNIA

Dr. **Johnson**. Thank you, Mr. Chairman. My name is Albert W. Johnson. I am a biologist by professional education and training, and I am at present Vice President for Academic Affairs at San Diego State University in San Diego, California.

Thank you for the opportunity to speak in support of this new $50 million program for academic research instrumentation. In my opinion, it is an excellent effort to bridge the gap between the National Science Foundation's existing instrumentation program and its support of large, one-of-a-kind facilities.

San Diego State University is a very large, comprehensive, doctoral institution. It has 35,000 students, 28,000 undergraduates and about 7,000 graduate students. That is approximately 10 percent of the total enrollment in the very large California State university system, about 350,000 students in that system. Our faculty come from the top graduate programs in the United States, and they are expected to devote about half of their time to teaching and about half to research. Thus, we are not in the mold of a typical research institution.

Our faculty nonetheless generates about $50 million in research support from Federal, State and private sectors annually. Most of our instructional needs are funded by the State of California. Unfortunately, major teaching and research instrumentation is an exception. The formulas in the State of California that drive the State budget in this critical area are simply inadequate to allow our faculty and students access to modern up to date research instrumentation. As a result, our faculty have had to seek equipment support in the resources generated from non-State faculty supported research.

Our College of Sciences, for example, has a current equipment inventory of $20 million, 60 percent of which, or $12 million, was obtained from non-State sources. An example may better illustrate our reliance on non-State resources to fund science programs of importance to the National and State well-being. Changes taking place in modern biology have revolutionized the curriculum. Programs such as genetic engineering are extraordinarily equipment-intensive, and the lifetime of individual pieces of equipment is relatively short, a few years at best.

In order for the California State university system to modernize its biology curriculum on its 20 campuses all at once—a formidable undertaking—it was necessary to organize a large effort to train faculty in this new thinking and methodology and to obtain the instrumentation to do so. This required the acquisition of equipment costing hundreds of thousands, if not millions, of dollars, in the aggregate.

Fortunately, the National Science Foundation was able to match State funds to help start this ongoing effort. In principle, these new programs will affect hundreds of thousands of students in the next few years. In the absence of State support, we shall require significant infusions of non-State money for several years, just in this one area. Although I am speaking about the education of California students, they do, after all, help supply the pool of trained scientists and technicians nationwide.

From my 27 years of experience, Mr. Chairman, as a teacher, scientist, and administrator, probably the most expensive piece of equipment I used as a scientist was maybe a $3,000 microscope. I know from my personal experience what a difference excellent instruction makes in our ability to prepare our students for the workplace, and for further graduate studies. One important component in science instruction is modern instrumentation. This initiative on the part of the Administration is a welcome addition to the NSF support base.

Thank you very much.

[The prepared statement of Dr. Johnson follows:]

TESTIMONY BY:

Dr. Albert W. Johnson
Vice President for Academic Affairs
San Diego State University
San Diego, California 92182

TO:

U.S. House of Representatives
Committee on Science, Space and Technology
Subcommittee on Science

13 March 1991

Thank you Mr. Chairman. My name is Albert W. Johnson. I am a biologist by professional education and training, and I am at present Vice President for Academic Affairs at San Diego State University in San Diego, California.

Today, I want to speak in support of the new $50 million program for Academic Research Instrumentation, in my opinion an excellent effort to bridge the gap between the National Science Foundation's existing instrumentation program and its support of large one-of-a-kind facilities.

San Diego State University is a large, comprehensive doctoral institution. Its 35,000 student enrollment (undergraduates 28,000; graduates 7,000) is approximately ten percent of the total enrollment in the California State University System. Our faculty, which come from the top graduate programs in the United States, are expected to devote about 50 percent of their time to teaching and about 50 percent to research.

Although SDSU is not a research institution in the formal sense, its faculty currently generate about $50 million in research support from the federal, state and private sectors. Most of our instructional needs are funded by the State of California, but, unfortunately major teaching and research instrumentation is an exception. The formulas that drive the State budget in this critical area are simply inadequate to allow our faculty and students access to modern up-to-date research instrumentation. As a result, our faculty have had to seek equipment support in the resources generated from non-State faculty supported research. Our College of Sciences, for example, has a current equipment inventory of $20 million; 60 percent or $12 million of which was obtained from non-State resources.

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From my 27 years of experience, Mr. Chairman, as a teacher, scientist and administrator at San Diego State University, I know from personal experience what a difference excellent instruction makes in our ability to prepare our students for the workplace and for further graduate studies. One important component in science instruction is modern instrumentation. This initiative on the part of the administration is a welcome addition to the NSF support base.

Thank you.

Mr. **Boucher**. Thank you, Dr. Johnson.

Dr. Przybylowicz?

STATEMENT OF DR. EDWIN PRZYBYLOWICZ, SENIOR VICE PRESIDENT AND DIRECTOR OF RESEARCH, EASTMAN KODAK, ROCHESTER, NEW YORK

Dr. **Przybylowicz**. Thank you, Mr. Chairman. I am Ed Przybylowicz, Director of Research for the Eastman Kodak Company and I thank you for the opportunity to appear at this hearing.

I would like to comment on several matters related to how the Eastman Kodak Company establishes its R&D capital budget, and from that standpoint I may be your token industrialist in this hearing. But I want to talk about that from the perspective of how we fund facilities and instrumentation in the industrial sector, and how we view the facilities and instrumentation issue that the academic institutions are testifying on here today.

In a formal statement provided to you earlier, I detailed some of the statistics involving Kodak's worldwide research and development scope and budget. In the interest of time, I will forego recounting those statistics at this time.

It should be noted here that the book value asset base of our research operations in support of the company's imaging sector is growing at a rate of about five percent per year. This growth is driven primarily by commercial opportunities. Research spending for facilities and equipment at Kodak reflect the company's overall strategic direction and its annual business plans. In addition, it is for the most part incremental, from an existing base of facilities and equipment.

In this process, cost justification is a critical element. As accurately as possible, we try to establish a return on asset yield for all capital investments. Let's look at two major components of a research capital budget, facilities and equipment.

At Kodak, the Director of Research serves as the landlord for the company's more than 1,000,000 square feet of laboratory space in Rochester. Each lab pays rent by the square foot, which includes depreciation expenses. This charge varies depending on the type of activity in the laboratory. Before investing in a new research facility or a piece of scientific instrumentation, we make a rent or buy decision.

Sometimes depending on the nature and circumstances of the project, it is better not to have total ownership of the facility or highly expensive equipment. An example is an agreement we recently had with the University of Rochester, when we wanted to conduct short-term research efforts related to AIDS. We offered to remodel an existing laboratory at the University of Rochester as a cost-effective alternative for ourselves to building a new lab from scratch.

Our laboratories in Europe often rent large, costly analytical instruments from university laboratories. We have had such an arrangement also for high field NMR at the University of Rochester. And to test the supercomputer waters a few years ago, we joined the National Center for Supercomputer Applications at the University of Illinois.

At this point, it might be useful to briefly point out the difference between industry and academia in the use of scientific equipment. Industrial research equipment is almost entirely focused on a specific task, either as part of a single project or as a shared resource among several projects. The purchase is generally justified by the expected volume of activity in support of business.

Equipment utilization at a university is more broadly centered on both research projects and the use of the instrumentation or equipment as an instructional aid. For example, an NMR spectrometer might be purchased through the funding of a specific project, but its long-term use will be to increase the knowledge of science students in general. This is an important dimension of equipment acquisition for universities.

In that light, I would like to conclude with a brief comment on what industry expects from graduates of our scientific and technical schools. Essentially, we expect our university graduates should be well-schooled in the fundamentals of science and they should have been trained in the most modern experimental techniques available. Current capabilities in such areas for example as analytical technology, biotechnology, computer science, began years ago in university laboratories. Today these technologies are opening new worlds in electronics, therapeutic drug design and information systems. There are numerous examples of practical applications from almost every basic scientific discipline.

Industrial and university laboratories may have different justifications for expenditures on scientific equipment and facilities, but they have a common mission. That is to increase the technical knowledge for the betterment of society.

Thank you.

[The prepared statement of Dr. Przybylowicz follows:]

Statement to House Subcommittee on Science
Dr. Edwin P. Przybylowicz, Director, Research
Eastman Kodak Company

Washington, D.C.
March 13,1991

This statement will consist of four parts: 1) A statistical overview of Kodak R&D, 2) The decision process for capital budgeting at Kodak, 3) a brief comparison of how universities and industry use equipment in Research, and 4) a statement of expectations industry has for the graduates of university science and technology schools.

1. Kodak Worldwide Research and Development

Kodak has research laboratories and facilities in six countries, including the United States. Offshore laboratories are in England, France, Germany, Japan, and Australia. In the U.S., our facilities are located in Rochester, New York; Kingsport, Tennessee; Philadelphia, Pennsylvania; Albany, New York, and San Diego, California.

These laboratories are dedicated to supporting the company's major business sectors: imaging, industrial chemicals and health. Rochester, San Diego and the offshore laboratories primarily support our imaging sector. Kingsport, headquarters city for Eastman Chemical Company, is the center of support for our industrial chemical business. Certain health care product research, such as x-ray film and diagnostic products, are supported in Rochester. Our pharmaceuticals research is done in Philadelphia and Albany.

Kodak's total R&D budget in 1990 was $1.3 billion. There are nearly 10,000 scientists and technicians working in our worldwide laboratories. Because of the global nature of our total R&D operation and the complexity of its organization, I propose to offer this committee my comments on a smaller slice of the Kodak Research capital budgeting process.

Essentially, I will be limiting myself to Kodak Research operations supporting our imaging sector. When I say "smaller," I do so in a relative way. Kodak's 1990 imaging segment sales totalled $7.13 billion. More than 4,000 scientists, technicians and others work in research and development related to imaging segment products and manufacturing processes. This work is carried out in all of our worldwide laboratories. Those in Rochester occupy well over one million square feet of laboratory space.

The current book value of our Research asset base in Rochester totals $208 million, with $75 million for facilities and $133 million for equipment. Equipment, of course, refers to the tools -- ranging from $3,000 computers to one million dollar magnetic resonance spectrometers -- which our scientists use to do their work. Facilities refer to the structures and laboratories that house the equipment. From 1987 to the present, our asset base has grown at an annual compounded rate of about 5 percent.

Research capital spending in 1990, for both facilities and equipment, averaged about 7 percent of total worldwide R&D expenditures. This percentage ranged from 2 percent for research supporting our well-established businesses to about 17 percent for new technology areas in which we are building a presence.

2. The Decision Processes for Kodak R&D Capital Budgeting

Research spending for facilities and equipment at Kodak is driven by the company's overall strategic direction and its annual business plans. The business and technical managers set goals or targets and the necessary capital to reach those targets is allocated.

Thus, facilities and equipment acquisition decisions are made in the context of business opportunities. Cost justification is a critical element in the capital expenditure process. As accurately as possible, we try to establish a return on asset yield for all capital investments.

In most but not all laboratories, capital expenditure decisions are "incremental." By that we mean that capital additions grow from the existing base of facilities and equipment. Exceptions might be found in those laboratories that are responsible for investigating and surfacing whole new technologies to support the company's future. Since the technologies are new to Kodak, the necessary research tools likely will not be part of the asset base. In no case should a capital investment be made without careful consideration of the cost and its relation to the business direction of the company.

Let's look first at how Kodak manages its research *facilities* -- those buildings that house more than one million square feet of laboratory space. Then we'll discuss the equipment/instrumentation part of the equation.

Facilities. The Research Director serves as a "landlord" for Kodak Research facilities. As "owner" of the facilities, the director then "rents" space to the various Research organizations. These rental costs vary in respect to the type of facility and include depreciation expenses. For example, space for chemical synthesis which requires a sophisticated ventilation system might rent for more than a lab which is using computer equipment to model color imaging systems.

As laboratory needs and use change, this system allows for easy conversion of space.

In many cases, capital expenditures for facilities can come down to a "rent vs. own" decision. This is particularly true when there is uncertainty associated with a new business or technology venture. This process has led Kodak to a number of innovative and mutually beneficial relationships with universities.

One example comes from an arrangement we have with the University of Rochester. Our Clinical Products Diagnostic Research Group needed to be close to the AIDS research being conducted at the university. The group's plan called for an investigation to last three years. Obviously, it would be impractical to invest substantial capital to build from scratch a special laboratory for this research. So we donated money and management assistance for renovation of existing laboratories at the University of Rochester.

At the end of the three-year period, the university will have a state-of-the-art biological research facility at no cost to itself. And Kodak gets the type of facility it needs for a short-term research project.

Equipment and Instrumentation. Capital spending decisions for scientific equipment and instrumentation fall into two categories: 1) Those dedicated to a project, and 2) Those that will be shared resources. Decisions related to the former center on what needs to be done to achieve the result within a specified time frame. In the latter, the decision centers on the estimated volume of multiple users. An example would be an analytical instrument used by chemists engaged in different projects.

The "rental option" also applies to equipment purchase decisions. This option is exercised when the demand from a single project or multiple users cannot justify the outright purchase of equipment. Again, universities come into this equation.

- Our laboratories at Harrow in the UK, for example, rent time on large, expensive analytical instruments such as mass spectrometers and electron spectrometers.

- We often collaborate in new areas of technology for feasibility of application to Kodak interests. One such collaboration is at the University of Rochester in the area of high field magnetic resonance spectroscopy.

- Participation in consortia is another means to get cost-effective access to expensive equipment. For example, several years ago we joined the National Center for Supercomputer Applications at the University of Illinois. This was an alternative to purchasing our own supercomputer. This has allowed us to obtain significant experience in applying supercomputer power to Kodak scientific and manufacturing problems without taking on a substantial capital cost burden. I might also add that our NCSA contract is a shared resource for many other Kodak units, as well as Research.

3. Industrial vs. Academic Use of Equipment

It may be helpful to the committee members for me to compare the use of research equipment in industrial and academic laboratories. As described earlier, industrial research equipment is primarily focused on a specific task -- either in a single project or as a shared resource among several projects. The purchase of equipment is justified by the expected volume of activity on the equipment relative to its cost.

In academia, equipment utilization is more broadly centered both on research projects and the use of equipment as an instructional aid. For example, an NMR spectrometer purchased through funding of a special research project may have been required to successfully complete the project, but its ultimate use will be to increase the knowledge of science students in general. This is a very important dimension of equipment acquisition in academia and leads to my concluding point:

4. Industry Expectations for Science Graduates

I would like to conclude with some brief comments on what is expected of the graduates of scientific and technical schools who come to work in our industrial laboratories.

First of all, we expect them to be well grounded in the fundamental theory of their field of study -- whether it be chemistry, physics, engineering, or mathematics.

Second, we expect them to be well versed in the modern experimental techniques of their field -- techniques that are required if research is to be done at the frontiers of a discipline.

Third, we expect graduates to be able to work in new areas of research which will call on this academic background to forge new understanding and new experimental techniques.

To meet these expectations, academic institutions must keep abreast with basic technology -- and in many cases, lead the way -- in an environment of rapid and continual change. In the process, they must provide students laboratory experimental training in the newest research techniques of these fields.

It has been demonstrated time and again, that a strong foundation in science is a necessary step for practical application of technology. For example:

- Advances in analytical chemistry -- in particular, the ability to measure and analyze trace amounts of materials -- helped develop the understanding for this country's leadership in semiconductor technology.

- We are witnessing today the emergence of new therapeutic drug technology that is based in fundamental knowledge gained through theoretical studies in molecular biology which began many years ago.

- Computer technology, which sits so conveniently on our desktops today, is the result of initial investigations by university scientists who assembled room-size pieces of equipment with a fraction of the power of the modern personal computer.

To make these breakthroughs, scientists needed to be well educated in the basics of science. While in the academic environment, they also need to have the right tools to become acquainted with the newest research techniques as well as acquire useful knowledge through experimentation. Industrial and university laboratories may have different justifications for expenditures on scientific equipment and facilities, but each has a common mission: to increase technical knowledge for the betterment of our society.

Mr. BOUCHER. Thank you.

Dr. Whitten, we will be happy to hear from you, sir.

STATEMENT OF DR. DAVID G. WHITTEN, DEPARTMENT OF CHEMISTRY, UNIVERSITY OF ROCHESTER

Dr. WHITTEN. Thank you, Mr. Chairman. I am David Whitten from the University of Rochester. Although I am a Department Chair and Director of an NSF Center for Science and Technology, I think my perspective is really that of an individual researcher and educator. I am very pleased to have a chance to offer my perspectives on the NSF budget request for fiscal year 1992.

The overall increases requested are most encouraging, and for the most part, the apportionment of funds seems reasonable. The Research Facilities Modernization Program has provided awards announced last month to a broad spectrum of institutions for a variety of worthy projects. The selection process used insured that these funds reached a truly representative segment of schools.

A major problem is that the potential need for funding in this area is clearly far greater than $20 million per year. While it is not yet clear that inadequate facilities are a major factor limiting the effectiveness of academic research, the long-term problem of deteriorating facilities and deferred maintenance is a very serious one.

In my own department, I estimate costs of renovating for new use existing or inadequately modernized lab space as $200 per square foot, or $160,000 for a four-person lab. We currently have more than 160 research students, so this translates to $6.4 million if we made a total turnover.

On the other hand, if I look specifically at real needs, deferred maintenance, in our building beyond renovations, we need a new roof at a cost of $1 million, and a repair modernization of our hood manifold system at $1.5 million. This does not yet impede our research to the extent that we cannot accept NSF grants. But someday it will.

Even the entire NSF budget request of $2.72 billion could only solve a fraction of this problem. It seems to me that the impact of $20 million per year is nearly negligible, but that we must, over the next few years, find a solution that will probably involve sources beyond the Foundation.

The Academic Research Instrumentation Program at $50 million per year can have a major positive impact on the research infrastructure in the U.S. It is probably the major, if not only, vehicle for obtaining instrumentation in this cost category for most academic institutions. The need for sophisticated and unfortunately expensive equipment is closely coupled to scientific advances in an increasing number of areas. Such instrumentation plays a key role in training students, and is closely coupled to the human resources component of science.

Although I find this program very attractive, I have major concerns on how colleges and universities can come up with the 50 percent match or cost share from non-Federal funds. This is a problem for State and private institutions alike, given the current economy and escalating operating costs. I would urge that the match requirements be somewhat relaxed to include renovations and development costs, as well as perhaps Federal matching funds.

To summarize, my recommendations follow the stated NSF priorities, in order, human resources, equipment, facilities. I think that above all, the top priority should be kept for direct funding of research, especially the badly-needed increase in these funds recommended in the budget request should be retained.

Secondly, I recommend approving the academic research instrumentation budget as recommended. Thirdly, I think that while the Facilities Modernization Program should be deferred as recommended, there must be a long-term plan, including funding from other sources, developed.

Thank you very much.

[The prepared statement of Dr. Whitten follows:]

Statement to the Committee on Science, Space, and Technology

David G. Whitten
Department of Chemistry
University of Rochester
March 13, 1991

It is an honor to be invited to offer my perspectives on the National Science Foundation (NSF) plans and programs for the fiscal year 1992 budget. As an academic researcher, and more specifically a chemist, I am most concerned with the total program of the NSF and in its role in furthering the research/education program of U. S. academic institutions. Recent advances in science and technology have made possible research opportunities that were beyond contemplation for the academic community only a few years ago; these new research endeavors in turn can make a tremendous contribution to the education of a new generation of scientists and engineers who will keep the U. S. at the forefront of the high technology arena. The central problems are of course the increasing cost of doing research and finding answers to the question of how to maintain the competitive edge the U. S. has acquired during the last half century. Academic institutions are faced with a number of challenges including the need to examine and adjust the advanced research/educational process which produces the future leaders of our national research and development activities. We are called upon to play a critical role in accelerating technology transfer and in advancing U. S. competitiveness. Changing demographics and a decline in the percentage of entering students interested in or seeking careers in science and engineering are having adverse effects on the supply of future professionals; projected retirements and attrition of the ranks of academic and industrial scientists over the next decade argue strongly for an increase in the production of advanced scientists and engineers. The importance of these persons in the U. S. economy can not be overexaggerated: for example, in my own field, the chemical industry with its $16 billion positive balance of trade and the closely related pharmaceutical enterprise are strongly dependent upon chemists and chemical engineers coming directly from programs in academic institutions. Recent pleas such as the ad in the February 14, 1991 *Wall Street Journal* (copy enclosed) speak pointedly to this concern. At the same time the reduction of the U. S. edge in high tech industrial competition with Japan and Germany suggests that we need to develop new educational programs which are more broadly based than those now offered by traditional individual science and engineering departments. Current tight budgets at most U. S. academic institutions constrain the research/educational activities and certainly hinder the development of new programs. Therefore the reliance on NSF and other Federal sources appears more critical than ever before as we address these challenges. With these considerations in mind, I am pleased to offer my thoughts and evaluations on the specific NSF programs for Research Facilities Modernization and Academic Research Instrumentation.

Research Facilities Modernization

The current program has provided funds to an impressive array of institutions for a large number of diverse projects. From the list of awards recently announced it is clear that much care has been put into the selection process. While the funds awarded represent a sound investment by NSF it is clear that the overall facilities situation for academic institutions in the U. S. represents a problem of perhaps 2-3 orders of magnitude greater financial level than the current appropriation. The problem is severe and gigantic. Given the number of academic research facilities constructed in the late 1960's to early 1970's and the advances in laboratory design and safety regulations in the intervening two-plus decades, it is clear that many of these are badly in need of renovation, or more likely, replacement. This does not represent an increase in the capacity or capabilities of academic research/educational facilities but more a maintenance of what we have. Given NSF budget realities it seems unlikely that sufficient funds are available either this next fiscal year or in the near future to tackle this problem. The NSF needs to address this need and the financial burden must be shared with both Federal and non-Federal agencies

Academic Research Instrumentation

The case made for the Academic Research Instrumentation in the summary (ARI-1,2) is compelling. Constant advances in instrument technology render the lifetime of state-of-the-art instrumentation very short, indeed much shorter than that of other research and education facilities. The development and acquisition of new instrumentation is a major component of most scientific research today and the availability of instrumentation has an immediate impact on the students involved in academic research. The specific level of support and type of instrumentation provided by the proposed program fills a current void and should have an immediate impact on interdisciplinary research endeavors. For instance, one example of the type of facility which might be provided by this program would be the development of a synchotron port at a National Laboratory such as Argonne or Brookhaven for use by chemists at an academic institution. Students using such a facility in photochemical studies would be afforded both new research opportunities as well as the exposure to a new research environment and coworkers from diverse scientific disciplines.

One of the major points concerning the ARI is that it will be highly leveraged through institutional cost sharing. Given the current economic situation and, more particularly, the financial status of most state and private research universities, I am not optimistic about the ability of prospective grantees to obtain the proposed 50% match from non-Federal sources (it is my understanding that original drafts required a 67% match). In our own institution the difficulty of obtaining matching funds has increased dramatically over the past two years reflecting the simultaneous growth of instrumentation needs and requests and the budget difficulties. It seems to me that changes to permit matches from other Federal sources, a relatively flexible interpretation of the institutional "match" to include either or both personnel (development) or renovation costs will be required to make the program effective.

Although it would not be wise to attach "strings" to the program, it seems that priority might be given to instrumentation requests which have an educational "value-added" component such as involvement of students in interdisciplinary projects. In this way the ARI program could have direct positive effects in developing new infrastructure such as linkages between science and engineering programs.

Summary

My assessment of the NSF program proposed for evaluation is as follows.

(1) Both the Academic Research Instrumentation and Research Facilities Modernization programs are worthy projects and funds are needed for support of both areas over the long term.

(2) The top priority in budgeting for the NSF should be the at least 16% increase in direct funding for research programs. This is in accord with the stated overall priorities for support in the following order: human resources, equipment and facilities and it is desperately needed at a time when the direct support for research/educational activities in academic institutions from other sources (state, industrial or institutional) is either eliminated or severely curtailed.

(3) The budget proposed is recommended on the following grounds:

(a) To respond to the question posed in the letter requesting advice to the Committee, my evaluation is that academic research is presently significantly impeded by short-comings in both facilities and instrumentation.

(b) The Facilities Modernization Program, while an excellent project, does not provide sufficient funds to have a major impact in science education. While funds will certainly be required for this activity in the near future, given NSF priorities and budgeting pressures, it is better to defer future funding for this program beyond the next fiscal year and concentrate where maximum value to the advanced educational process can be obtained.

(c) The Academic Research Instrumentation program directly supports the human resources development and the funds provided in the budget make possible advances which would otherwise be unobtainable. The proposed program offers benefits in both addressing severe needs and providing new opportunities to obtain maximum value in maintaining the U. S. lead in academic science.

CAN AMERICA AFFORD TO LOSE ITS LEAD IN SCIENCE & TECHNOLOGY?

American leadership in science and technology has never been as evident as now. But within this decade, our nation's long-standing competitive edge in science could be lost.

This concern is not the idle speculation of a handful of commentators, but felt throughout the American scientific community. The results of a Gallup survey completed just last week among our scientific leaders show the concern to be widespread and based on emerging manpower and funding problems.

What are some of the reasons for concern?

- Reduced math and science skills of our secondary school graduates.
- Established scientific investigators needing to spend one-third of their time seeking scant grant opportunities instead of doing research.
- Young investigators abandoning research for better-paying, more-secure jobs.
- The "graying" of our scientific community, in which attrition seriously depletes our senior scientific manpower.
- Our college-age population is shrinking, with many talented students disinterested in pursuing careers in university-based research.

Throughout the 20th century, America has led the world in discovery research. Will our leadership in science and technology disappear as we approach the new century? The answer is within our grasp to shape. But complacency in the face of current success will surely shape it to our disfavor.

The symptoms of that unfavorable outcome may be obvious in the form of numerous job vacancies. Or the symptoms may be subtle. Instead of unfilled positions in academic or industrial laboratories, we might see a slowdown in the pace of biomedical research or a gradual movement of American biotechnology firms abroad. These developments would be the result of the market adjusting to a U.S. manpower supply insufficient to meet the demand. The question is whether we take the chance that things will work out for the best or act now to ensure that the problem does not arise. The nation can ill afford this kind of gamble.

America has demonstrated the capacity and will to be a world leader, from societal issues to scientific progress. The obstacles to fulfilling our scientific agenda are many and complex, but they can be solved through decisive action now.

Nowhere have the results of our nation's scientific agenda been more apparent than in the life sciences, and nowhere is current success more widely cherished. Every American is the potential beneficiary of medical progress. Citizens of every country have also shared the benefits of that progress.

The research-based pharmaceutical companies of the United States are proud to be an important and integral part of the nation's collaborative research process — a process that has historically been supported by the ongoing initiatives of the federal government. Advances such as the Salk vaccine and antibiotics were made possible by the support of the National Science Foundation and the National Institutes of Health. Supported by Congress, both have underwritten much of the basic research that has led to successful clinical applications, which in turn have saved countless lives.

Help America's biomedical research community maintain yet another point of light that shines brightly throughout the world. By supporting educational and research funding that will attract and retain the high caliber and quantity of scientists we need, you will help preserve America's leadership in medical progress.

Sheldon G. Gilgore

Sheldon G. Gilgore, M.D.
Chairman, PMA Foundation
Chairman, President, and CEO, G.D. Searle & Co.

Pharmaceutical
Manufacturers
Association
Foundation, Inc.

This message has been underwritten by the Pharmaceutical Manufacturers Association Foundation, which invites you to support continued growth of federal funding of scientific research by writing your Congressmen and other legislative representatives.

Wall Street Jnl 2/14/91

Biographical Sketch

of

David G. Whitten

David G. Whitten was born in Washington, DC, in 1938 and earned his Ph.D. at the Johns Hopkins University in 1963. After 2 years of military service (Jet Propulsion Lab), he spent a year of postdoctoral study at Caltech (1965-1966). He joined the faculty of the University of North Carolina at Chapel Hill in 1966 (M. A. Smith Professor, 1980) and moved to the University of Rochester in 1983 where he is currently C. E. K. Mees Professor and Department Chair. He is also Center Director of the NSF Center for Photoinduced Charge Transfer at Rochester, a cooperative venture involving the University, Eastman Kodak, and Xerox. At Chapel Hill and Rochester, he and his co-workers have carried out studies of thermal and photochemical reactions in solution, at interfaces, and in microheterogeneous media. His group's photochemical studies have focused largely on redox reactions, isomerizations, and fragmentations. He has served on editorial advisory boards of the Journal of the American Chemical Society and The Journal of Physical Chemistry and as an organizer of several scientific conferences, including the Xth IUPAC Photochemistry Symposium. In addition, he was President of the Interamerican Photochemical Society from 1983 to 1986.

Mr. **Boucher**. Thank you, Dr. Whitten. The Chair extends its .thanks to all our witnesses this morning.

Dr. Whitten, let's begin the questioning with you, and we will pick up with your last point. I am well aware of the fact, I think we all are, that there is a total national need for research facilities that greatly outstrips the ability of any Federal agency to fund it. I am told that need could be $10 billion or maybe $12 billion, nationwide. I think none of us would suggest that the Federal Government ought to fully fund that $10 billion or $12 billion research facility need.

On the other hand, isn't there some role for the Federal Government to play in assigning a priority to what the really good projects are, and the NSF program does have that attribute. It is a peer review process that does assign priority. Then, shouldn't we allow that to happen, and then get the benefits of leveraging of other investment from other sources that would follow that assignment of priority by NSF?

Some of the testimony we have received suggests that as much as 50 percent to 60 percent of the total cost of the project would come from other sources. That would then follow the lead of the NSF. What general comment do you have about the appropriateness of the Federal program in light of those perceived benefits from it?

Dr. **Whitten**. As I say, I think the current program is a good one. I think the $40 million or so that was just announced is certainly well spent money and I think the review process was well used in selecting these projects. But I think it is totally inadequate. As I indicated in my statement, I think very easily NSF could spend all its money on facilities. I think right now that probably has a lower priority, at least at the moment, than direct support of research or the instrumentation program.

So my concerns are, sure, this is a great program, but I think more money needs to be found. Unless you are going to give NSF a lot more than they asked for, you can't adequate meet this with this kind of program.

Mr. **Boucher**. Let me get a comment from the panelists generally about the condition of the research infrastructure today. Can the current infrastructure, given its age and the lack of modernization that exists at many facilities across the country actually support additional research projects? I wonder if Dr. Wyatt, you might begin to answer that.

Dr. **Wyatt**. I would be happy to take a stab at it. I think there are two degrees to this issue. There are some kinds of research projects that require certain instrumentation—protein sequence counters, computers, special fume hoods. If we take the latter category, just take a fume hood that would support toxic materials, you just can't do the research without it. So either you have this kind of facility or you don't do the research. In fact, if a building won't support clean power, that is electrical power that does not create difficulty, create electrical noise that would disturb an experiment, then you have to clean it up before you can do that.

There is another, more subtle kind of facility problem here, and that falls in the computer area. If one has a computer that operates at 1 megaflop, 1 million floating point operations a second, one can do experiments in meteorology with a grid size that is 20 square miles. That's perfectly good research. It will probably produce some interesting findings.

On the other hand, as the FCCST report indicates, we had access to computer systems that operated about 20 terraflops, 20 trillion floating point operations a second, we could reduce that grid size down to about 5 kilometers, and therefore begin to look at microactivity that would allow an enormous improvement in our ability to deal with weather forecasting and meteorology. So there is sort of the go/no go kind of issue here, about which we are very concerned.

But we are also concerned about the quality of the facility and its instrumentation, in order to stay at the leading edge of many of these research fields.

Mr. **Boucher**. Dr. Johnson, do you have a comment?

Dr. **Johnson**. My general comment on the question, Mr. Chairman, is that the technology that has been developed in the last 20 years so far outstrips the ability of State institutions to pay for it that there is really no way that any state institution except one that has access to significant Federal or private funds can afford to modernize all its laboratories at the same time. It is just out of the question.

What has happened in my institution as a result of this is that we have attempted to concentrate our efforts, and use our money where we think we can mount a good program with excellent faculty. But by no means can we cover the field. The technology is moving fast, changes rapidly, instrumentation is very expensive, especially the kind we are talking about today.

So I think the research infrastructure—and let me just speak for State institutions like the one I represent—is simply not able to deal with the problem.

Mr. **Boucher**. One of the concerns that had been expressed during presentations yesterday is that on the one hand, the National Science Foundation is recommending no funding for research facilities modernization, and at exactly the same time, State budgets are being stressed and are placing bricks and mortar construction at a lower priority generally.

So building new buildings and modernizing existing buildings becomes the lowest priority project across the board. To focus my question a little more directly, in light of those facts, does it make a lot of sense now to be investing broad new sums in programmatic expenditures, and for matters such as instrumentation, if the current laboratories can't accommodate those new projects and the new instruments themselves? Do we have a problem in that sense, is that a valid concern?

Dr. Johnson, would you like to comment on that?

Dr. **Johnson**. Yes, thank you. I believe it is a problem. However, in this category we are talking about, with equipment from $100,000 to $2 million, I think most existing laboratories can handle that kind of equipment. At that size, we are not talking about the sort of equipment that requires many new buildings, or things of that sort. It may require the modernization of a laboratory. It may require a more dependable power supply, as Dr. Wyatt pointed out.

Also, I am in a somewhat different situations, because the State of California, in recent years, has funded all its capital outlay by bond issues from the people. So we have done reasonably well in capital outlay. That is not one of our major problems at the moment.

Mr. BOUCHER. Okay. Dr. Whitten?

Dr. WHITTEN. Again, I would like to speak to this general question. When I look over our campus, I see that many of our buildings were built in the mid-1960s to early 1970s. So our facilities are very much stressed. But up until now, when we have obtained funds to acquire instrumentation, we have been able to get money from the institution. That's getting increasingly more difficult to do. That's why I ask that that specifically be put in the cost share.

But I think that is one way of getting institutions to come up with the funds. I have not heard of many cases— until now—where funds from the Foundation have not been accepted because of facilities not being adequate. It is a real problem. It is going to be an increasing problem as these facilities get older, but I think at the moment it is not as severe as the instrumentation need.

Mr. BOUCHER. Okay. Dr. Przybylowicz?

Dr. PRZYBYLOWICZ. Just to reinforce what my colleagues on the panel have said, I think you can't separate facilities and instrumentation from programs. That's one integral— when you are talking about a new program. When we look at our asset base of some $200 million, for every $2 we spend on equipment, we spend $1 on facilities. That's not new buildings, not new brick and mortar, but it is renovation of facilities so they can handle either meeting new OSHA regulations, new ventilation requirements, containment isolation facilities for working with toxic or hazardous materials. That has to be looked at as a complete package with the program, I believe.

Mr. BOUCHER. So you would argue for both facilities and instrumentation funding?

Dr. PRZYBYLOWICZ. Yes. And I think that's what Mr. Wyatt said in his opening statement. I think that's an important issue.

Mr. BOUCHER. Let me focus a little bit on a point made in your prepared remarks, which was that Kodak, for its new initiatives in research, expends perhaps as much as 17 percent of the cost of the total project in both facilities and equipment. What would you recommend the appropriate level of expenditure as a percentage of the total project cost be for a modern research university?

Of the total project cost, what percentage ought to be in facilities and equipment? Is 17 percent the right number, or do you think that given the additional educational mission of the university, that it ought to be a higher or lower number than that?

Dr. PRZYBYLOWICZ. I think that 17 percent, as I mentioned in my oral comments, we try to cost justify owning a piece of equipment or having a facility of our own based on the traffic that it bears. If you add to that the additional instructional dimension that an academic institution has, it may have to be higher than that number.

Mr. BOUCHER. The Chair's time has expired. I am pleased to recognize the gentleman from California, Mr. Packard.

Mr. PACKARD. Thank you, Mr. Chairman.

Dr. Wyatt, you have strongly supported the continuation of the facilities modernization program, yet recognizing that there is only $50 million earmarked for both that and instrumentation, what would be your priorities if you were given an opportunity to have access to some of those monies in terms of modernization versus instrumentation?

Dr. WYATT. I think that is going to vary from one institution to another. I think our need we are working at now is modernization of our science and engineering laboratories. We have managed to produce efficiencies at Vanderbilt, I think, by having joint projects between the sciences, medicine and engineering, in many cases, coalescing together and sharing space, using generic laboratory space.

In our facilities area, we would look at this, as I said earlier, as a package arrangement, very much like Kodak does. We look at a research project. We begin to look at facilities needs. We try to be sure that we are efficient in the expenditure of that. How it breaks down and how much goes exactly for instrumentation. How much for bricks and mortar type space and other facilities, will vary from project to project.

If $20 million or $17 million is the mean, the standard of deviation on that would be quite large. For example, a quantum chemist can burn up quite a bit of computer time, just one individual might run an instrumentation number that is 90 percent of the project cost, whereas other projects will not run quite that high.

Mr. PACKARD. Dr. Johnson, you stated in your testimony that the College of Science at San Diego State has a current equipment inventory of about $20 million, 60 percent of which comes from non-State sources. What are your sources for most of your funding for equipment, and is it easier to get instrumentation money or modernization money from State and private sources?

Dr. JOHNSON. To answer your last question first, it is much easier to get instrumentation money than it is facilities modernization money from State and private sources. On your first question, the sources of funds for our equipment, in addition to the State, 60 percent is from Federal agencies, the National Science Foundation, the National Institutes of Health, the Department of Energy and many others. Some state agencies, instead of the general fund appropriation we get, private companies, engineering companies, technical companies around the Nation, are often generous in their award of funds, or donation of funds for equipment.

Those are about the major sources. We have very little philanthropy in State institutions in California, as you probably know.

Mr. PACKARD. Dr. Whitten and Dr. Wyatt, is that true also from your institutions? Is it easier to get instrumentation monies from your State and private sources than it is to get modernization? Dr. Whitten, you first.

Dr. WHITTEN. To answer that, to the best of my knowledge, it is not easy at all to get instrumentation funds outside of Federal sources. We get small amounts from various sources, occasionally a little bit from New York State. But it would be very hard from within the University to get major instrumentation. That would be a very low priority item. Given our current budget situation, it would be hard to get repairs and modernization funds. But I think we have a better chance of getting them.

Again, to give you an example of the kind of leveraging you can have, we were awarded one of the science and technology centers in the first competition in 1989, I believe, and part of that was a requirement for institutional renovation. So the lion's share of the renovation funds came from the institution. The institution tried hard not to put that money out, but the institution did finally come up with those funds as its contribution. I think the institutions in general will do that. I think they can find money for that. They can't find money, certainly, to purchase instrumentation of this sort.

Dr. WYATT. I have a quick response. I think generally our experience is that industry and corporations are more likely to look favorably on a request for instrumentation funds or a joint venture to which they can contribute instrumentation, and generally are skeptical about fundraising proposals that call for major development of space. That is generally because they are looking at a short-run project orientation for these kinds of facilities.

By the way, the research and development tax credit helps us a good deal. I think it would help more if it were made permanent.

Private individuals, generally before the Tax Act of 1986, were more instrumental in getting new space built. But the Tax Act of 1986, because of putting gifts of appreciated property under the alternative minimum tax has really dramatically hurt us for large gifts. That's where wealth of that sort is accumulated, in appreciated property or securities.

So we have seen a drop at Vanderbilt, and I know it's true at Yale, in large gifts of appreciated property. And it is true of several other institutions. I just happen to know of those two. It has dropped to one-third of what it was several years ago. So we are being caught from all sides, we feel, in trying to deal with this issue ourselves. We are partners with the Federal Government. We want to be good partners, but we are having great difficulty holding up our end because of a series of actions on the part of the Federal Government.

Mr. PACKARD. Dr. Przybylowicz, did Kodak curtail its contributions and involvement with institutions as a result of the changes in the Tax Act?

Dr. PRZYBYLOWICZ. I don't think our involvement with academic institutions has changed significantly. In fact, if anything, our R&D, external R&D, has increased over the last two or three years. But those increases are all programmatic in nature. Rarely will we give or donate equipment to an academic institution, unless it happens to a piece of equipment we manufacture.

Mr. PACKARD. I guess the thrust of my question is, if there is to be a limit of $50 million in the program, would it be to your advantage to eliminate, as is being proposed, the modernization monies, and have it earmarked predominantly for instrumentation? Would it be better to reverse that, or leave it flexible, to be used either place? One answer would be sufficient, Dr. Wyatt?

Dr. WYATT. In my view, the flexibility would be very important. We need to look at the project and its needs and then go from there.

Mr. PACKARD. That's generally the way the panel would feel?

I won't take any longer. Thank you, Mr. Chairman.

Mr. BOUCHER. The Chair thanks the gentleman and recognizes the gentleman from Arkansas.

Mr. THORNTON. Thank you, Mr. Chairman. Let me first say that I appreciate the good testimony by the panelists. My personal view, Mr. Wyatt, is to agree with you that we need a balance between instrumentation and facilities. In striking that balance, it becomes very important to understand the questions which have just been pursued about how best to magnify the Federal contribution to this project by springing additional support from State and private hands.

I am deeply concerned that the proposal does not contain money for facilities, because I think that is one of the ways in which the Federal Government can obtain a multiplier effect, by springing private and public funds from State sources.

Do you agree generally with that statement?

Dr. WYATT. I do indeed. In fact as I said, and I believe it is very difficult for me to draw a crisp line between instrumentation and facilities—that's just impossible in most of the projects with which I am personally familiar.

Mr. THORNTON. In regard to facilities, I think we do need to bear in mind across other committee structures the effect of tax consequences such as you have outlined, the availability of trusts which can enable donors to make gifts of current income. My own experience is that it's a bit easier to get private donors to create a $10 million Bell engineering center—and that's not Bell telephone, that's an entrepreneur named Bell—or a cancer research center or an engineering technology center, because they identify themselves with the brick and mortar and having their names on the exterior of the facility.

Whereas, it is much more difficult to raise private money for an electron microscope or a new laboratory device that may be absolutely critical.

What would you think might be a matching or incentive type grant program which would ripen in the eyes of potential donors, the possibility of raising private money?

Dr. WYATT. I think the matching leverage that you get now generally in the competitive framework that characterizes NSF research projects is good. I really think we need to take an holistic view of this and consider all the aspects of financing such ventures, joint ventures with industry. Some relief on the gift of appreciated property would help us a lot.

The way I look at it, if it's in the best interest of this country to modernize our research facilities—and I strongly believe it is, for our competitive position and everything else, then we ought to try to do it with as few Federal dollars as we can. If we can figure out ways for the Federal Government to get these facilities with our help, all of us working together, for 10 cents on the dollar, or 20 cents or 30 cents, or 50 cents, that's a whole lot better than 100 cent dollars.

We need to look, I think, at the whole package. Research and development tax credit is an element, gifts of appreciated property is an element, contracts, grants, requirements for matches, special incentives from the State for the States to establish these high tech centers that do help the economy of the State. I think all of this needs to be looked at together. That's not what we are getting when we get these arbitrary fences built that we don't even understand between things like instrumentation and facilities.

Mr. **Thornton**. I know that on most campuses such as yours, which have really done an extraordinarily good job, there has been a lot of strategic planning, allocation of resources, not trying to move out into every area, but to specify. Do you think that kind of strategic planning might be suitable as a means of solving the kinds of problems we are talking about?

Dr. **Wyatt**. I think in many areas it is a good idea. It is done, and I am encouraged, by some of the strategic planning that produces centers of activity for certain kinds of research. Our competition in winning the free electron laser facility at Vanderbilt is a good example of that.

The thing that characterizes the National Science Foundation, however, is that it is probably the only basic research area around that is available to just about any member of any faculty who wishes to put together the initiative to do a proposal and have it judged. So we need to protect this relatively small and special area of basic research that is provided by the Foundation.

But the point these gentleman have made, better than I have, is that with even with small projects these days, in any science, one needs facilities and instrumentation. You just don't do this with the popular lore in your garage any more.

Mr. **Thornton**. Absolutely. I would like to ask the other members of the panel to make any comments they choose with regard to this line of questioning.

Dr. Johnson?

Dr. **Johnson**. Let me pick on the last point and use the example I quoted in my testimony. When the California State University, this enormous giant, was confronted with the prospect of having to modernize biology all at once, it established what is called the California State University Program in Education and Research in Biology, CSUPERB is the acronym.

The system is now focusing its very limited abilities to provide this kind of equipment and facility support in that particular area. It has become a system-wide project involving faculty from all 20 campuses. Other things are not being done, but that one had to be done. That was a very, very high priority. It is unthinkable to send a biology major out into the world if he does not know anything about cloning of genes.

Mr. **Thornton**. Absolutely. Dr. Przybylowicz?

Dr. **Przybylowicz**. One of the collaborative programs that Kodak is involved in is the Center of Biotechnology at Cornell with Cornell University. That was a program which brought many different disciplines from across the University together to work in the general field of animal biotechnology. It became very clear, and I served on the board of directors of that group during its inception years, it became very clear to us at the beginning of that program that the existing facilities at Cornell could not accommodate the program as it was conceived, because of the nature of the technology that had to be put into place.

It led to state funding, actually, through the New York State Dormitory Authority of facility, with the requisite instrumentation in some cases built into the facility to be able to conduct that program.

I guess all that example does is underscore the fact that has been pointed out several times here and that is that facilities and instrumentation cannot be separated in the context of looking at what programs you want to conduct. More importantly, it is a major factor in part of the total program costs.

Mr. THORNTON. And it also underscores, by giving us success stories, the importance of this kind of funding. I appreciate that underscoring.

Dr. WHITTEN. I come to concerns over trying to find a multiplier. I think that's definitely good if the Foundation can get more from its money, but I find it's increasing more difficulty to do. In New York State, for example, New York State funding has virtually dried up, with the budget crisis. Our center, which is an interdisciplinary activity, was promised funds by New York State at the time of our application. These funds have never been forthcoming. The climate now indicates that it is very unlikely.

I think we have already heard that private donors are in relatively short supply, and then given the financial constraints, the situation on our own campus, it is very difficult to see where these funds are going to come from.

Mr. THORNTON. Thank you very much. Thank you, Mr. Chairman.

Mr. BOUCHER. The Chair thanks the gentleman, and recognizes the gentleman from New York, Mr. Boehlert.

Mr. BOEHLERT. Thank you, Mr. Chairman. I want to welcome the distinguished panelists, particularly my neighbors from New York.

I think the President's budget, overall, deserves very high marks for the treatment of science. I want to start by congratulating the Administration for a very good budget in the science area.

Having said that, however, I must admit a little dismay at some of the priorities. For example, and I will address a specific question to all the panelists. I find it difficult to accept a budget that has zero for facilities, nickels and dimes for instrumentation, yet a 120 percent increase in funding for a project down in Texas called a Superconducting Super Collider.

I have sat on this committee for nine years. During that nine year period, the SSC has evolved. Witness after witness has said to us in essence that "We would accept and embrace the theory that we should proceed with this project, if we proceed with it in addition to all the other things we feel have to be done."

Well, we are proceeding with it, but a lot of the other things that need to be done are not being adequately addressed. I guess in frustration I plead with all of you to give us some guidance on how we should best assign priorities. Do you, for example, find it acceptable that in one area we get a 120 percent increase for a project, while in another critical area we get absolutely nothing?

Without putting your neck on the line on this specific endeavor, and I can appreciate the problems revolving around that, can you give us some guidance on how we go about assigning priorities? It is a tall order, I know and one that I continue to wrestle with. Does anyone want to venture forth into that mine field?

Dr. **Wyatt**. I will put my head into the noose first. You are certainly correct in that it is a tough call. I believe before you came in, I too congratulated the Administration on its strong interest in science and its support of it.

I think we don't do enough long-range planning, long- range planning generally, in those areas that are as critical to the future of this Nation as the areas of research and development. Having said that, it does not make it necessarily easy. Takes the SSC—it is just not going to be possible to do the level of research in high energy physics at that level without an instrument like that. You can't do it if you don't have the instruments. So that is a long-term look at something that says this is a commitment, more or less, for civilization to look at this particular narrow area.

Not all research, however, is like that. A member of our faculty, Stanley Cohen, won the Nobel Prize two years ago for a discovery of epidermal growth factor. Stanley got interested in why certain baby mice opened their eyes earlier than others. It did not take a lot of instrumentation for Stanley to pursue this, it took him 30 years to figure this out. But in the process, he discovered a process in the DNA that relates to the abnormal growth of cells, cancer cells, and it can be used other ways, to grow skin faster.

If someone had come along, if my friend Senator Proxmire had heard about Stanley's project about baby mice opening their eyes, it would have gotten the Golden Fleece award. Yet it has become, after 30 years of work, a very important discovery.

I think that there is no any easy ground here. But I do think we need to have forums in which we can look at how much to devote to this, that and the other, recognizing that some research is going to require major instruments, some is not. A balance is really necessary, and keeping track of this balance is the appropriate thing.

What bothers me, as I said before, are these microactions like this arbitrary separation between instrumentation and facilities and other sort of almost appearing to be knee-jerk activities that impeded what we are trying to do, and don't allow us actually to spend money as well as we could if we had a longer look, a holistic approach, to what it takes to do certain kinds of projects and commit ourselves to it in the long run, then just roll up our sleeves and get together with panels of experts and decide like we do many other things on the priorities for this year, where we are going. Then maybe we could review it very carefully each year.

I believe we are making some progress in the Congress and the Administrative branch in this. But we need to get there faster than we are getting now.

Mr. **Boehlert**. Thank you. Are there any other panelists who have observations on this? Dr. Johnson?

Dr. **Johnson**. The great majority of academic science is devoted to producing students, graduates, the next generation of scientists. They are not working at the level of the SSC. They are working in their laboratories, bench situations in which their instrumentation does indeed fit into the categories we are discussing today.

But I suppose 90 percent—I guess I am reluctant to give a percentage. A large proportion of the money that NSF grants to science and academic institutions is based on that assumption, that it is important to maintain the vitality of the science establishment nationally, and it is very important to keep producing the next generation of scientists. I believe that should be a number one national priority, those two aspects.

On the other hand, the Nation has to have large priorities in terms of keeping itself ahead and up to date and looking forward to exciting new challenges. I think the SSC is like that. So I think it is an incredibly difficult problem, when you are strapped for money, to decide which of those things ought to be done.

As an academic scientist, I have no trouble saying that I hope academic science can be supported better than it is, and I am less concerned, myself, about the SSC, given the kind of institution I come from. But I can see it from the national point of view. We must go to the moon. We must do other things that are exciting and challenging and capture the imagination of people. Actually, then in the long run, they turn out to be very valuable things.

Mr. BOEHLERT. I am taking names and numbers here, because I want to have some further communications with both of you on the SSC. I am curious—is Vanderbilt involved in any, shape or manner with the SSC?

Dr. WYATT. Yes. We have some physicists who will use it in their experiment. We were part of a proposal, one of the finalists. Tennessee was one of the finalists in that competition. In fact, I am personally on the Board of the URA, the organization that runs FermiLab and will, I suppose, run that facility when and if it is completed.

Mr. BOEHLERT. Thank you. I'm glad to have that qualified.

Thank you all very much for your testimony.

Mr. BOUCHER. The Chair thanks the gentleman and recognizes the gentleman from Indiana, Mr. Roemer.

Mr. ROEMER. Thank you, Mr. Chairman. I have been very interested in your testimony and very thankful for it today as well as my colleagues expressed. Also, in being a freshman member and a new member up here, I have a number of frustrations already. One of those is being on the Education Committee and going back and forth between the Education Committee and the Science, Space and Technology Committee.

I constantly hear our witnesses saying that our academic institutions and research facilities are crumbling. We are not investing enough in science and math for our kids in second and third grade. Our eligible kids in Head Start programs are about 20 or 30 percent. While I applaud the Administration's efforts on the National Science Foundation and in many ways its science budget, we are in deep trouble internationally and domestically if we cannot come together on a national agenda, a national priority in our education system.

Dr. Wyatt, I am delighted to hear you say that we need to look at the long-term. We need to set National vision and National priorities. But nobody is doing it. We are not giving that kind of national attention to education on the home front. In one of my counties back in Indiana, I have a 25 percent dropout rate in a strictly rural county. I am not talking about inner city.

I guess my question is more, and you put your neck in the noose earlier, Dr. Wyatt, and I will ask you to keep it there. How do we focus on a longer look and longer investments, and long-term vision on investment in education, both from your perspective at Vanderbilt and from a perspective to finally put this on the national agenda in this country? If we are worried now about the Japanese and the Germans competing against us in 1991, we have not seen anything yet, from my limited time here in two months, as to where we are going across the board, educationally. It is very, very worrisome.

Dr. **Wyatt**. My own personal view, and I agree with you completely, I have spent a good deal of my personal time in the last three years working on this K-12 math and science education problem. I know a lot more about it that I did a few years ago. It is very, very alarming.

I think we are going to have to work together. Every citizen in the country, the Congress of the United States, the Executive Branch—we are going to have to work together like we have never worked together before in order to deal with some of these issues. They are systemic and infrastructure issues.

We know, for example, right now, that the students who come to Vanderbilt University, even though it is a very selective process and they are high performers in their high schools, often come to the University not having had good courses in certain subject area—calculus or language or English—through no fault of their own, just the school system and their community were not up to speed.

This infrastructure problem goes right back to the roots. We are losing some bright young minds out there in rural American and in the inner city and a lot of other places simply because they don't have access to good education. Many of them have problems right from the beginning. That's what Head Start is all about.

But even with Head Start, we have to take a whole new systemic look at this problem. I am encouraged that my colleague Lamar Alexander—I hope he gets voted in today— and the Congress working together, will begin to look at our education and research activity as a total system and in the long range.

I think if we don't do that, this episodic behavior that I think this country has been able to use over a period of time, and it is indeed a part of the democratic process, is going to have to be refined some in the sense of a strategic planning kind of infrastructure for the country that involves our leading policy makers and those we elect to office.

Let me just say this. It sounds corny, but I am proud of people like you who are willing to do what it takes to go through to get elected to an office like yours. I never have done it, and I probably won't but I know how strenuous it is. I think we need to communicate with you better here, whether we agree or disagree, on the issues we have to address and develop some more time than we have to working together on these large national systemic problems.

I could go on,but I have gone on too long.

Mr. **Roemer**. Would anyone else like to compound on that?

Dr. WHITTEN. I would like to say that universities are doing a lot now, I think. In our own university, through our center, we are doing quite a bit with outreach. But there is so much more that needs to be done. And I don't think it is a problem that can be fixed in a couple of years. I don't think you can remedy a system that has been left for years in neglect.

I think there are too many students per teacher, and I think the teachers, in many cases, especially in the areas of science and mathematics, are not sufficiently qualified to be teaching in some of the middle grades. It is a big problem and it will take a long time. There will not be any Band-Aid solution.

Mr. ROEMER. Mr. Wyatt, you seem to be pretty forthcoming in these areas. I am going to try to tighten the noose around you a little bit here, and ask you a question about earmarking. On the one hand up here, the testimony we just heard makes a case to some degree that we should not earmark in Congress. It is unfair. It targets and focuses too much money to a few specific institutions. In this morning's Washington Post, we saw that the Government Operations Committee is investigating a couple of schools for their use of funds on such things as yachts and gifts and things they should not be using Federal monies for.

On the other hand, we heard your testimony saying that we may need to focus more of these monies toward specialized labs, and instrumentation programs, and modernization of centers for excellence. I guess this comes back to one of my colleagues' questions, how do we reconcile the two? What kinds of things as a member of Congress should we look at to evaluate these programs and should we look more at the generic labs as opposed to the specialized labs?

Dr. WYATT. To pick up the end of the question, then I would like to get back to the first of it. One of the efforts of the Colloquium on research facilities is, as I said before you arrived, to look at laboratories nationally, like the Kodak laboratory and other industrial labs, to look at university labs and to see if we can arrive at a tightening of the construction costs for these facilities, to try to get that down. They are expensive.

Also, to try as best we can to provide guidelines for building laboratories that can be cycled as instrumentation becomes obsolete. Instrumentation becomes obsolete in about three years, sometimes less. By obsolete I mean there is an instrument better, that not only produces a higher quality result, but usually does it faster and cheaper. So there is this cycling going on, and we would like to find a way to construct laboratories that we can exchange instrumentation without high cost.

To get back to the notion of earmarking, and I would just focus on science and research facilities. Science is a competitive process. This country's greatness in science research is based on the spirit of competition, pushing each other for investigatory methodologies and so forth that lead to new knowledge. It just works. No other country can match us, or has ever been able to match us, when we use this competitive process.

I am really alarmed, if we get to the point where we are earmarking 25 times as much money for science research and facilities as we are awarding competitively. The number I saw in the Chronicle, as I said earlier, are close to half a billion in earmarks. We are talking about $20 million here. I think it is a balance issue. I can understand how some members would want to enhance their district by having a science research facility in it.

But I would really caution all of us to think about the advantages of the competitive awards and the judgment of panels experts. I think that works pretty well. There may be some problems, but I think it really works quite well, on the one hand.

Our ability, with that holistic view, to generate more and more resources, to enable the Federal Government to get its money's worth and more, for every dollar the Federal Government puts in, it gets more than a dollar's worth out of the other parts of the infrastructure. I know that is possible to do. That is really the reason I think we should be earmarking in this particular area.

Mr. ROEMER. Thank you. Thank you, Mr. Chairman.

Mr. BOUCHER. The Chair thanks the gentleman. The gentleman from Maryland, Mr. Gilchrest.

Mr. GILCHREST. Thank you, Mr. Chairman. Mr. Roemer kind of took my line of questioning, but I will add a little more to it.

Dr. Whitten, you referred to a more broadly based educational program. Some of that has been talked about in the last few minutes. A more broadly based educational program, I would assume, starts in kindergarten, goes through the 12th grade, and upgrading of colleges of universities. The problem is, how do we upgrade public schools in a country this size? It might be easier in Japan. And to a degree it might be easier in Germany.

We are so diverse, and we have so many different cultures and so many different problems. I am just going to throw out two things, Dr. Whitten, then I would ask you to respond. One is, would it be possible for certain colleges and universities across this Nation to team up with public schools in their regions for maybe a series of seminars throughout the year where, especially the public school teachers, I suppose, which really need the upgrading in these areas like science, math and English, team up in an effort to give the public schools, beginning with kindergarten, because that's where you can start teaching science, through the 12th grade, a continuous upgrading on new research and new discoveries? They might be able to get credit for it. The enthusiasm that is generated could go a long way.

Is that kind of thing possible on a regional or national scale?

The other thing, a recommendation for class size, I think is almost at the crux of this whole thing. You have a classroom of 30 7-year olds, or 30 10-year olds, who are all going in different directions with one teacher in that class. That seems to be a need that should be addressed in an aggressive way, also.

Dr. WHITTEN. We have tried to see, for example, both in our Center and in our department, how we could help. What things we could do. I think what struck us is where we feel we are best equipped to make a contribution is by working with the high school teachers, and perhaps with the junior high school teachers.

We have developed a consortium in Western New York, especially through the Center for Photo-Induced Charge Transfer, whereby we are working with teachers, both bringing them into the Center, developing instrumentation, perhaps you have heard of the new atomic forces microscope, and scanning microscope which allow people to actually see atoms. We have developed an instrument which will bring to the high school laboratories, at a fairly low cost, the capability to have students see atoms and actually have a real experience that was not possible before.

We have worked with the students, to some extent, having a symposium for the students to come in. But that is more difficult to do. I think so far, what we have seen, is that we really can have an impact by working with the teachers. I think now at the high school level, perhaps in the future at the level below high school, junior high or secondary schools, we might be. But I think that's where we can have a major impact, as far as retraining teachers, things like that, the universities can do a very good job.

Mr. **Gilchrest**. You have a program where the teachers actually come to the university in a seminar type setting, or on a regular basis?

Dr. **Whitten**. We have a program where the teachers come by on a regular basis. That's one. We have developed these laboratory instruments. We are getting a small company in New York State to produce them. We have had regular symposia throughout Western New York State involving groups of high school teachers, to come in and show them how to use it, to actually bring in classes.

We are working with high school students coming in on a two or three times a year basis to the university to hear discussions from faculty. We will probably put in regular seminars for the high school teachers. We have talked to them about how we can help, what they would find attractive. These are in response to their inquiries.

Mr. **Gilchrest**. Could this be a model program that would be shared with other areas?

Dr. **Whitten**. I think especially our development of the scanning electron microscope is something that probably could be used much more widely. We are looking into that.

Mr. **Gilchrest**. Is this anything you have written down, that I could get a copy of?

Dr. **Whitten**. Yes.

Mr. **Gilchrest**. We have talked in this committee about supercomputers and high performance computers that could connect the Nation's laboratories and schools. Is this something that could be used as a model for enhancing the quality of education, science and math, and all other areas, when this thing eventually gets connected?

I guess what I am asking is, it seems to me that one of the keys that can unlock the potential for students and people becoming interested in science and math so we don't lose our competitive edge, and we don't lose our ability for research and development, is that sense of enthusiasm among young people. If we can tap that and find out how to do that, even if it starts on a small scale and begins to spread, and in the long term I think it will be successful.

Dr. **Whitten**. We are very hopeful that this can have that kind of impact. We think it very well may. After all, in chemistry, up until now, certainly at the high school level, students write down equations, they look at atoms in a very abstract way. That is hard for them to do. To actually see the structure of graphite. To see how the atoms are arranged. To see individual atoms is a very exciting thing. The fact that this can be done on a small scale we think will have an enormous potential impact. It can provide a bridge to interest students in science, to make them go further. So we are hopeful.

Mr. Gilchrest. Thank you very much. Thank you, Mr. Chairman.

Mr. Boucher. The Chair thanks the gentleman, and recognizes the gentleman from Florida, Mr. Bacchus.

Mr. Bacchus. Thank you, Mr. Chairman.

I would like to address my remarks to Chancellor Wyatt. Chancellor, my home is in Florida. I live there and represent the people there. But I was born in Nashville, Tennessee. My grandparents were from Southern Kentucky, in tobacco country up there, my mother's parents. They went to a one-room schoolhouse in Derryville, near Price's Mill. In the 1920s, their family lost their land in the agricultural depression that preceded the great depression. At the age of 18, they got married and moved to Nashville.

My grandfather worked in a filling station as a mechanic across the street from Vanderbilt University. When I was a boy, he used to tell me how, in the 1920s, some of the famous Vanderbilt professors would come to have him fill up their cars with gas, Robert Penn Warren and John Ransom and Donald Davidson. He always took pride in the fact that they knew him by his first name, and that they treated him like somebody.

In my family, there was only one university, and that was Vanderbilt. I think the proudest day of my grandfather's life was when Vanderbilt gave me a full academic scholarship. I would like to say thank you to the University today for doing that. I am the first person in my family to have an opportunity to get a college education. I would not have done so had Vanderbilt not given me that opportunity. I am very grateful and look forward to making the University proud of my service here.

I agree with you wholeheartedly in what you said today, and I think many of us will be attempting to shift some of the priorities in the NSF authorization toward more modernization of facilities. In particular, though, I have been struck by some of what you said about ways of encouraging private investment. Clearly we need more public dollars. I would like to see us spend much more publicly on these kinds of facilities for all the reasons that have been mentioned.

But you have mentioned some specific ideas about encouraging private investments, and leveraging. I would appreciate it if you would expand on that beyond just the permanent research and development tax credit. If you could talk about some of the ideas you allude to in your testimony and the attachments from the Colloquium about private bonds, and about gifts, other ways that we might encourage cooperative efforts.

Dr. Wyatt. I would be pleased to do that, Mr. Bacchus. That was a wonderful story, and I appreciate it. Speaking for Vanderbilt, we are very proud of you. That's the value of the education system in this country, that we cannot lose, so that any youngster who is willing to work and who has the potential to do it has a chance to attend a good university and receive all the educational benefits thereof. You will be interested to know that one of the ways I spend most of my time now is trying to raise $300 million in a campaign we are doing, most of which will go to scholarships for people who would not otherwise be able to come to Vanderbilt.

Let me address your second question. I think in looking at this issue holistically, that is to get methods of leveraging dollars, you heard an example this morning that I will call to your attention again, that Kodak has decided on a cost benefit basis, that is by looking—they had a project they wanted to do, and they decided that the most cost effective way to do it would be to lease some space in a laboratory at the University of Rochester, do the project that has a finite life, and then probably convert that laboratory for some other use later on.

We have not done nearly as much as I think we can do in joint ventures between American industry and universities. I think there is another major issue that has not been mentioned that I want to describe. We know that most of the products and services in the world today had their origins in some sort of scientific discovery. We can argue also that most of those scientific discoveries occurred in the laboratories in the United States of America, and mostly in university laboratories, although the industrial laboratories now are fabulous. In many cases they are better, because they have better facilities and good people, than the university laboratories.

But what we have not been able to do is move discovery from the laboratory quickly into American products and services. As a matter of fact, many of the goods that are manufactured outside this country are a result of discoveries that were made in this country. But some other nation was above to move them into a very effective product faster than we can in this country.

Mr. BACCHUS. Magnetic levitation, for example?

Dr. WYATT. Absolutely. There are many examples that would could all cite. In fact, we are in danger of losing communications in computers right now, which is a major struggle. The list goes on and on. Pharmaceuticals—it is practically endless.

By having closer ties between universities and industry, by providing incentives that you all can think of or that we can think of together, and things like this Colloquium we are working on, and many other types of organizations, we can not only get more of the Federal dollar. We can not only develop better strategic plans, but we can also deal with this issue of taking discoveries that are made here and moving them more rapidly from a competitive point of view into American products and services. I don't believe we have yet made much of a dent in that problem. I think we understand it better than we did, but I think that may be the major benefit, in addition to the financial issues we have described, in working on this for the future of the country.

Mr. BACCHUS. Thank you, Chancellor. I have one final personal note. My 20th reunion is scheduled for Memorial Day weekend. I have hopes of being there. However, my wife and I are expecting our second child on Memorial Day.

Dr. WYATT. Oh, my goodness. Well, we have great facilities at the Vanderbilt Medical Center. We can take care of that. Come on down.

Mr. BACCHUS. If I am not there, I hope you will understand.

Dr. **Wyatt**. I will, indeed. But we would love to have you.

Mr. **Bacchus**. Thank you. Thank you, Mr. Chairman.

Mr. **Boucher**. The Chair thanks the gentleman and recognizes the gentleman from Illinois, Mr. Bruce.

Mr. **Bruce**. I have no questions of this panel.

Mr. **Boucher**. With the Chair's thanks, this panel is now dismissed. Your testimony this morning has been extremely helpful to us, and we will certainly consider that carefully, as we have ongoing deliberations with respect to the National Science Foundation's fiscal year 1992 budget request.

Thank you very much.

We now welcome the second panel for today, and that consists of Dr. Rochus E. Vogt, Professor of Physics and Director of the LIGO Project, at the California Institute of Technology, in Pasadena; Dr. Clifford Will, Professor of Physics, Washington University, St. Louis, Missouri; Dr. Anthony Tyson, Physics Research Laboratory, Bell Laboratories, in Murray Hill, New Jersey, and a member of the NSF Advisory Committee for Astronomical Sciences.

Gentlemen, we would ask you to come forward at this time and without objection, your prepared statements will be made a part of the record, and we will be pleased to receive an oral summary of those statements. The subcommittee has a five- minute rule with respect to oral statements and we would ask that you limit your oral testimony to that period of time and we will propound questions following that.

Dr. Vogt, we will be pleased to hear from you first this morning.

STATEMENT OF DR. ROCHUS E. VOGT, PROFESSOR OF PHYSICS, DIRECTOR OF THE LIGO PROJECT, CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, CALIFORNIA

Dr. **Vogt**. Thank you, Mr. Chairman. I am Rochus Vogt, Professor of Physics, and Director of the LIGO Project at the California Institute of Technology. I appreciate the opportunity to appear before you today.

LIGO stands for Laser Interferometer Gravitational-Wave Observatory. The project is a joint effort by scientists and engineers at the California Institute of Technology and the Massachusetts Institute of Technology to design, build and operate a national observatory to detect and study gravitational waves. The existence of gravitational waves was predicted in 1916 by Einstein in his Theory of General Relativity.

More recently, theoretical physicists have come to understand the details of how these waves are generated in the cosmos. Many of the dramatic discoveries of modern astronomy, such as quasars, pulsars, and black holes, should produce strong gravitational waves.

Experimental research and development for the detection of gravitational waves has been pursued for the past 30 years. We have now advanced the state of the art of a particular technology, namely laser interferometry, far enough to propose, with confidence, the construction of the world's first gravitational wave observatory.

This facility will enable scientists to study new areas in both physics and astrophysics. Its unprecedented sensitivity will assure a rich harvest of results. LIGO will explore the universe, including as yet the unopened window of the gravitational force. Laboratory physicists are developing the technology, but astrophysicists as well as physicists will be the users of LIGO. They will observe gravitation waves to study, for example, how a neutron star, a 10-mile size ball of nuclear matter, is born in a supernova explosion, or how two neutron stars behave when they collide at almost the speed of light. They will be able to prove the existence of black holes, regions of such intense gravity that even light cannot escape from them.

LIGO will also enhance modern physics in the non-linear phenomenon of gravitation, and into the behavior of nuclear matter. LIGO presents opportunities to the broad scientific community. After construction, it will be operated at a national facility, and it will provide the means for researchers from even small institutions to share in and contribute to carrying out its research. Over its lifetime, the project will present a superb opportunity of the training of students who will be leaders in the science and new technologies.

The LIGO program has already been a strong driver for technology development for industry and university interaction. Examples of these technologies are significant advances in the art of precision measurements, with a precision that is many millon fold higher than the benchmark for atomic clocks, and the development of highly efficient, high stable and high precise lasers.

The LIGO technology also was a driver in extending supermirror technology, as used in laser gyroscopes, to larger apertures and new wave lengths. It is developing sophisticated vibration isolation systems, and it has introduced cost effective new approaches to the construction of large volume, high quality vacuum systems.

All of these technologies have significant commercial and military applications.

As the cornerstone of the new scientific discipline, LIGO has been extensively reviewed and enthusiastically endorsed by interdisciplinary panels of physicists and astrophysicists. Major reviews took place in 1986, 1988 and 1990. I would be happy to provide the names of the reviewers if the committee so wishes.

LIGO represents a formidable and rewarding challenge to a scientist by combining frontier exploration with high technology development. The timeliness of the project is evident from the high level of interest throughout the world. LIGO will be the first step in establishing a worldwide network of gravitational wave detectors acting in concert.

The leadership of the United States is crucial in this pioneer research.

Thank you, Mr. Chairman. This represents a summary of my prepared statement.

[The prepared statement of Dr. Vogt follows:]

Testimony of
Dr. Rochus E. Vogt

R. Stanton Avery Distinguished Service Professor
and
Professor of Physics
Director, Laser Interferometer Gravitational-Wave
Observatory (LIGO) Project
California Institute of Technology

Before the
Subcommittee on Science
of the
Committee on Science, Space, and Technology
United States House of Representatives
March 13, 1991

Mr. Chairman and Members of the Subcommittee:

I appreciate the opportunity to appear before you today to discuss the LIGO project, which is part of the President's budget request for the National Science Foundation.

The LIGO project is a collaborative effort of scientists and engineers at the California Institute of Technology (Caltech) and the Massachusetts Institute of Technology (MIT) to design, build, and operate a Laser Interferometer Gravitational-Wave Observatory (LIGO). The observatory will consist of two facilities, separated by more than 1,500 miles and operating in unison to detect and study gravitational waves from astrophysical sources. When completed, LIGO will be operated as an observatory open to the scientific community. The title of the project describes both the purpose of the facility and the technique to be employed: to establish an astrophysical observatory for the study of the universe via the medium of gravitational waves. The technique to be used is based on laser interferometry—the use of light to measure minute relative motions of objects.

Perspective: It is a great privilege and challenge to head an effort to open up the next frontier of astrophysics. Since the beginning of history, mankind has tried to understand the nature of the universe and the natural laws that govern it and us. This understanding is one basis of our civilization and our well-being.

For millenia, our primary tool for studying the heavens was visible light and the human eye. Galileo gave us the first telescopes, and ever since, our power to observe has been enhanced by increasingly sophisticated and powerful optical observatories. The development of radar during World War II brought us radio astronomy which, paired with optical astronomy, started the modern revolution in our view of the universe. Today we are using a powerful multidisciplinary and multispectral approach to the investigation of the universe and its laws, including radio, infrared, optical, ultraviolet, x-ray, and gamma-ray astronomy.

But all of these techniques are derived from of one single fundamental long-range force, the electromagnetic force. LIGO is designed to exploit the waves generated by the only other long-range fundamental force, the gravitational force.

Gravitational-wave astronomy: In the same way as the radio waves transmitted from a concert hall bring to us the music of our composers, gravitational waves have imprinted upon them the story of the physical events that generated them. LIGO is designed to detect these faint whispers from the universe, to decode the messages, and to derive from them information on events far away in space and time, and to derive knowledge for human society. Electromagnetic waves are produced by atoms in the surface layers of stars or by charged particles in electromagnetic fields and can be obscured by matter. Gravitational waves are generated by near light-speed motions of star-size objects, and they penetrate everything with impunity.

The predicted sources of gravitational waves include the most energetic and bizarre astrophysical phenomena: supernovae, neutron stars, black holes, and even the Big Bang. Gravitational waves will tell us how a neutron star (a ten-mile-size ball of pure nuclear matter) is born in a supernova explosion. They will reveal to us the star-quakes that wrack this neutron star throughout its life, increasing our understanding of nuclear physics. Gravitational waves will allow us to prove the existence of black holes, regions of such intense gravity that even light cannot escape from them; in fact, they represent the only tool available to study directly the dynamics of black holes, which are postulated to power the most energetic objects in the universe. Gravitational waves will tell us about the orbital dance of binary neutron-star or black-hole systems, which, because of their emission of gravitational waves, will spiral closer together and ultimately coalesce in gigantic cataclysms. The Big Bang itself will have produced a background of weak gravitational waves bathing us continuously. This background will carry clues about the relationship of gravity to the other fundamental forces.

All of these phenomena which we can anticipate, are predicted on the basis of knowledge derived from electromagnetic astronomy. It is my firm conviction that even greater knowledge will derive from surprises, the astrophysical processes that cannot be predicted from electromagnetic astronomy. The opening of each of the new windows in astronomy has led to such surprises, forcing us at each step to expand our view of the universe around us. Radio astronomy brought us pulsars and quasars. Infrared astronomy pinpointed the hidden birthplaces of the stars. Gravitational-wave astronomy has the potential to produce surprises beyond even these. The knowledge gleaned through this window, alone and in combination with its sister discipline, electromagnetic astronomy, will put us in a much more powerful position in our quest for knowledge and understanding.

Gravitational Physics: Gravitational waves hold great promise as a tool for probing the nature of gravity. From the effect of the waves on the detectors we can infer the mass and the rate of spin of the fundamental particle that carries them, the graviton. And from the symphonic information carried by the waves, we expect to learn how gravity behaves when it is so strong that gravity, by itself, without the help of matter, creates gravity. A black hole in space is the ultimate product of the nonlinear process in which gravity creates gravity. (Similar nonlinear processes—but not gravitational ones—are responsible for holding a tidal wave together as it travels across the ocean, for holding together the Great Red Spot on Jupiter, and for the chaotic behavior of many dynamical systems.) Nonlinear gravity is responsible for the existence of black holes and determines their dynamics. With LIGO we expect to watch—or maybe I should say listen to—a black hole deform and then vibrate when a neutron star falls into it, and we expect to watch two black holes collide, and their nonlinear gravity struggles to hold itself together and form a single, larger hole, amidst the symphonic din of crashing vibrations of space-time. Moreover, we expect theoretical physicists, using supercomputers, to try to simulate these black-hole collisions by solving Einstein's general relativity equations. This interplay between theory and experiment will surely be a fruitful one.

Existence of gravitational waves: Gravitational waves were predicted by Einstein as part of his Theory of General Relativity in 1916. The detailed physics of gravitational waves and their sources were elucidated by a generation of theoretical astrophysicists in our time. The effect of gravitational waves was observed in the 1980's in radio-astronomy studies of a binary pulsar system which exhibits orbital decay by gravitational-wave emission, in perfect agreement with relativity theory. But the effects of gravitational waves are extremely feeble, and their direct measurement and exploitation is technically feasible only now. That the time is ripe for this new initiative is demonstrated by the progress of scientists all over the world engaged in efforts to establish laser interferometer gravitational-wave observatories, an enterprise in which the United States so far has played a proud and leading role.

LIGO Project: The LIGO project is a joint effort of scientists at Caltech and MIT, who originally pursued independent programs, but formed a joint project in 1984 that today represents the sole U.S. effort towards the construction of a laser interferometer gravitational-wave observatory. The LIGO team will design, construct, and operate an observatory, consisting of two widely spaced similar facilities (more than 1,500 miles apart) that provide an enclosed vacuum system for housing laser interferometric gravitational-wave detectors. Each facility will consist of an L-shaped system (see Attachment A) incorporating vacuum tubes (beam tubes) 2.5 miles long for each arm, with interferometer components or laser beams at the corner, end, and mid-stations.

The scientific importance of the LIGO project and its technical feasibility have been endorsed by a large number of reviews (see Attachment B, "LIGO Project Milestones") including the National Science Board, committees empaneled by the National Academy of Sciences, and peer review panels of the National Science Foundation. The enabling Research and Development (R&D) for LIGO has been funded by the National Science Foundation since 1979.

LIGO technology contributions: The LIGO project has been able to attract an outstanding science and engineering core staff because it combines a focus on some of the most fundamental science issues and the founding of a new scientific discipline with a leading-edge engineering challenge. The LIGO project looks forward to a continued close interaction with industry with a two-way flow of information and invention. LIGO is stimulating the development of powerful new enabling technologies with potential industrial, defense, and space applications.

These include:

High precision metrology: This project is developing the capability to perform measurements to a precision of 1 part in 10^{23} in a hundredth of a second. For comparison, the metrological precision of atomic clocks is now a few parts in 10^{15} over the period of hours. The laser stabilization techniques developed by this project have been adopted as standard practice in precision measurement laboratories.

Laser development: LIGO demands a new generation of lasers combining high efficiency, high power, and outstanding short-term frequency stability (better than 1 part in 10^{17}). The commercially available gas-tube lasers now in use consume huge amounts of electricial power. The new green-light solid-state lasers under LIGO development will have superior performance and more than 100 times better efficiency. These advances have applications including scientific spectroscopic research, commercial large-screen projection TV, and underwater communications.

Mirrors, optical components, and coatings: LIGO, in close collaboration with industry, has pushed the performance of "super-mirrors" for green light to the highest level of performance (losses less than 20 parts per million). An important application of similar mirrors is in laser gyroscopes, with commercial and military applications. LIGO has developed techniques for testing and certifying these mirrors which have been adopted by industry.

Vibration isolation systems: LIGO is developing both passive and active (servo-controlled) vibration isolation systems with unprecedented performance. This technology will be needed in the semiconductor industry's push of photolithography towards increasingly small wavelengths.

Cost effective methods for large volume high-quality vacuum systems: The LIGO vacuum system will be by far the largest high-quality vacuum system ever built, and considerable effort has been expended by the LIGO engineering team on its design. The vacuum tubes of a single facility total 5 miles in length, with a diameter of 4 feet, and must provide a vacuum of better than 10^{-10} torr. In order to achieve this extremely high-quality vacuum over such a large volume at tolerable cost, a melding of techniques from the pipeline industry and the high vacuum industry needed to be achieved. In addition, conventional stainless steel contains too much hydrogen contamination to be economically feasible, so a special stainless steel which has vastly lower hydrogen content was developed with an industrial partner. To achieve this goal, industry demonstrated a new production technique to LIGO specifications, and the LIGO project developed new, high-sensitivity test procedures for industrial use. The success of this program has been confirmed by the LIGO project team in a large-scale demonstration.

Detector technology: Gravitational-wave detection has been pursued actively in the laboratory since the 1960's, starting with the "resonant-bar" technology. Advanced versions of resonant-bar detectors are in operation in the United States and abroad today. However, the ultimate sensitivity of this technique is much poorer than that of laser interferometric detectors, and its main use is to search for phenomena in our own galaxy, which occur very infrequently. No confirmed, direct detection of gravitational waves has yet been achieved.

Laser interferometric detectors were proposed in the 1960's and have been under active development since the late 1970's with funding from the National Science Foundation. The laser interferometric technique is sensitive to a wide range of sources and is capable of observing gravitational waves from as far as the edge of the observable universe. And therefore, thanks to the large volume of space under study, it promises to expose a large range of phenomena. Furthermore, the technique is inherently broadband, allowing us to view the waves' time evolution, from which we can unravel the history of the events producing the waves.

LIGO technique: LIGO will detect gravitational waves by using "free-mass" detectors. A pair of test masses is suspended from thin wires, free to move parallel to the ground. A passing gravitational wave will cause changes (l) in the separation of the two masses in accord with the wave's encoded information. The effect of the gravitational wave on the masses is proportional to their initial separation (L). Thus, the larger the initial separation of the masses, i.e., the larger the detector, the more sensitive it can be. The information about the gravitational-wave source is inferred from the motion of the test masses—their movements are a vastly scaled-down echo of the processes that produced the waves.

Hence, a good sensitivity requires the capability of measuring minute displacements (l), which primarily needs experimental skill, and a large size detector (a large L), which requires a costly, large vacuum system housing the test masses. A high vacuum ($\sim 10^{-10}$ torr) is needed for the laser beams that measure the separation of the test masses by interferometry, since scattering from gas molecules would introduce unacceptable noise into the measurement.

Theoretical predictions indicate that the majority of extragalactic gravitational-wave signals will have wave amplitudes (h) of 10^{-20} or smaller. The detection of such a wave amplitude in a 2.5-mile long detector requires the capability of measuring the displacement of an object (l) of 4×10^{-15}cm, which is less than a millionth the diameter of an atom. This capability exists today in a 130-foot length prototype detector on the Caltech campus, which represents, because of the smaller size, an amplitude sensitivity of 10^{-18}. A vigorous R&D program underway, consisting of laboratory work, theoretical modeling, and design, has identified further refinements that, together with a 100-fold facility scale-up to 2.5 miles, will allow an ultimate gravitational-wave amplitude sensitivity for burst-type sources of $h \lesssim 10^{-23}$. This sensitivity provides an excellent basis for the study of a large number of astrophysical phenomena.

The technical implementation of the LIGO interferometers uses an L-shaped geometry, where two pairs of test masses are arranged at right angles to each other. Light from a highly stabilized laser is divided by a beam splitter and directed along the two arms. The test masses carry highly reflective mirrors which bounce the light back and forth a number of times before bringing it back together at the beam splitter. There the light from the two arms is accurately compared to search for infinitesimal motions of the test masses. The ultimate operational LIGO interferometers will derive their capability from sophisticated vibration isolation, thermal noise suppression, high laser power, and advanced optics.

Even the most advanced designs, however, will not be able to suppress all local disturbances that could be confused with gravitational waves. It is therefore mandatory to operate at least two widely separated detector systems in unison. This allows the suppression of all influences except the correlated gravitational-wave signals. Further reliability comes from the operation of a half-length interferometer, whose signal must be exactly half that of a full-length interferometer.

Timeliness: LIGO has been developed for more than a decade through scientific R&D, prototyping, design, and large-scale demonstrations to a point where most enabling technologies have been proved. It is now necessary to proceed to the full scale (2.5-mile arms) facilities to perfect those techniques that can only be tested full-scale, and to begin subsequent operations. This final phase will require availability of both of the widely separated facilities for final shakedown, since verification of the most advanced techniques needs the same measurement sophistication as the actual observatory operations.

The initiation of this final phase is timely in view of the state of readiness of the project, but also for logistical reasons. In order to accomplish the conceptual scientific and engineering design, a core team of specialists had to be assembled and trained solely for this purpose. To dissolve this team now would not only sacrifice a uniquely effective resource, but also would deprive the project of the "memory" of this team to be used in the supervision of industrial construction contractors.

Technological risk assessment: Although the technology challenges involved in LIGO are substantial, the key technicial elements have been tested and proven. The most important cost element in the project is the vacuum system, which has been the subject of extensive development. Laboratory experiments to determine the specifications for the materials, processes, and designs have been validated with large scale demonstrations. The risk associated with the major cost elements of the facility is therefore very low.

The sensitivity actually achieved with the interferometer depends on the confluence of a number of technical elements: highly stabilized lasers, sophisticated anti-vibration systems, super high reflectivity mirrors, among others. Many of these elements have been separately demonstrated to the levels projected for initial LIGO operation; others can be demonstrated in their entirety only on the full-scale LIGO system. Our calculations and experiments have revealed no fundamental or technical limits to the interferometer which would prevent us from reaching our stated sensitivity goals.

Like all developments of scientific techniques, experience with the use of the facility and advances in technology will lead to continued improvements of the laser interferometer detectors.

LIGO site selection: A site solicitation for the two U.S. locations is underway and will be conducted according to procedures and criteria approved by the National Science Board. The site solicitation was announced in the *Commerce Business Daily*; also all 50 governors' offices were provided with the announcement. Deadline for receipt of proposals was March 1, 1991. We received a surprisingly enthusiastic response given the very demanding criteria for LIGO sites. Eighteen proposals from seventeen states were received and are being evaluated.

Budge. and schedule: The President's budget proposal contains a startup amount of $23.5M of a total 5-year program of $211M. The spending profile contemplates comparable expenditures in years 1 and 5, with approximately double this amount in years 2, 3, and 4. A schedule for phasing the construction task is provided in Attachment C. The construction of the two LIGO sites will lag each other by about 1 year for optimal use and phasing of industrial construction.

Operations cost of the LIGO observatory, after construction, including the support of the Caltech/MIT LIGO team, will amount to about $10M/yr.

International collaboration: The two-site LIGO will be an autonomous observatory. LIGO by itself will be able to unambiguously identify gravitational waves and to conduct a significant scientific program of research in physics and astrophysics. However, the determination of gravitational-wave source positions requires a minimum of three interferometer facilities, and becomes even more powerful with a larger number. This requirement comes from the fact that a single laser interferometric gravitational-wave detector has limited intrinsic directional sensitivity: the direction to the source of the waves must be determined by triangulation, using the arrival times of the waves at three or more detectors, much as in a phased array of electromagnetic detectors.

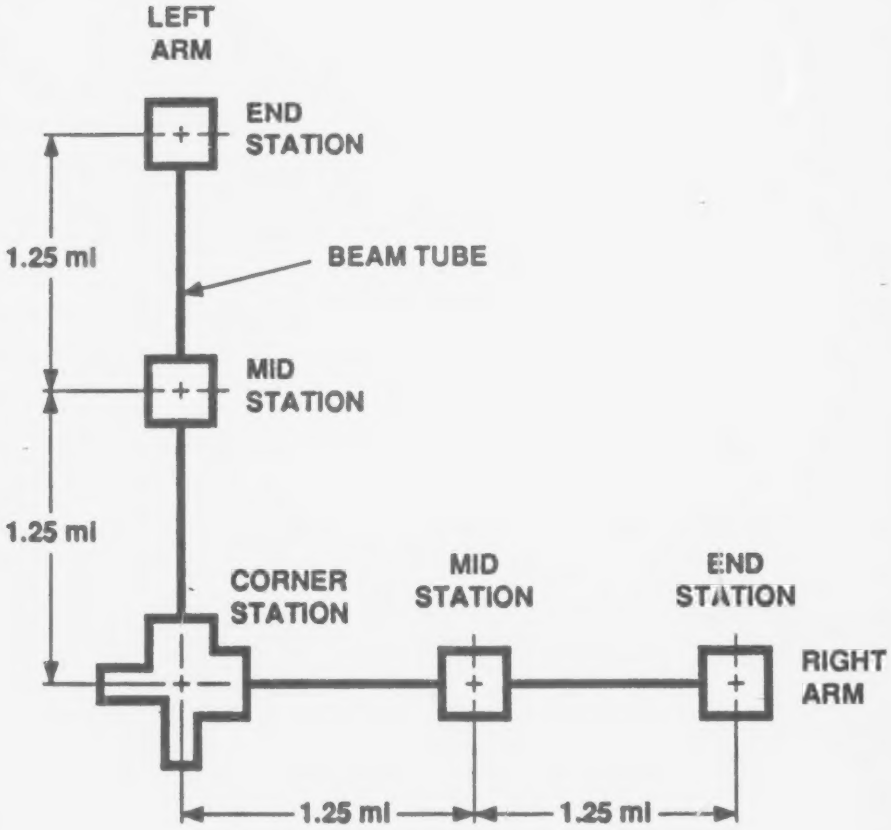
LIGO will be the first step in establishing an international network of gravitational-wave detectors. Two European groups (a British-German collaboration and a French-Italian collaboration) are proposing to build two LIGO-compatible gravitational-wave detectors in Europe and similar efforts are being considered by Australia, Japan, and possibly others. We expect that the success of the early results from LIGO and other facilities will, in fact, spawn the construction of a global network of laser interferometer gravitational-wave observatories, and that therefore many options for coordinated observations will exist, similar to the successful conduct of long-baseline radio astronomy.

LIGO—A national user facility: When fully operational, LIGO will become a national user facility, managed and operated by the Caltech/MIT team, and open to the scientific community. While LIGO will be primarily a gravitational-wave observatory, it will be exploited for other uses, piggy-back or dedicated, such as geophysical strain measurements or laser testing in a space-like environment. Already, collaborative programs have been established with Stanford University (for laser development), University of Colorado at Boulder (for anti-vibration platform development), and Syracuse University (for thermal noise suppression). It is expected that an approval of the LIGO program by Congress will precipitate a significant number of additional collaborations in technology development.

The eventual operational phase will, of course, bring in a large national user community. The two LIGO facilities are designed to ultimately accommodate a total of nine laser interferometers, six at one site, and three at the other site, which can be operated in a variety of combinations, depending on objectives. LIGO is designed to accommodate several independent experiments or users simultaneously and without interference, in order to serve with maximal flexibility as an effective national facility. In addition to those national users who independently or collaboratively wish to install or use interferometers and perform observations, the LIGO team will perform a continuous gravitational-wave "watch," and these and other data will be available to a second user community for analysis.

While some may view LIGO as "Big Science" because of the cost of construction, the resources required for being a productive user of LIGO are modest. LIGO will offer research opportunities to a wide range of institutions, from large universities to small colleges.

ATTACHMENT A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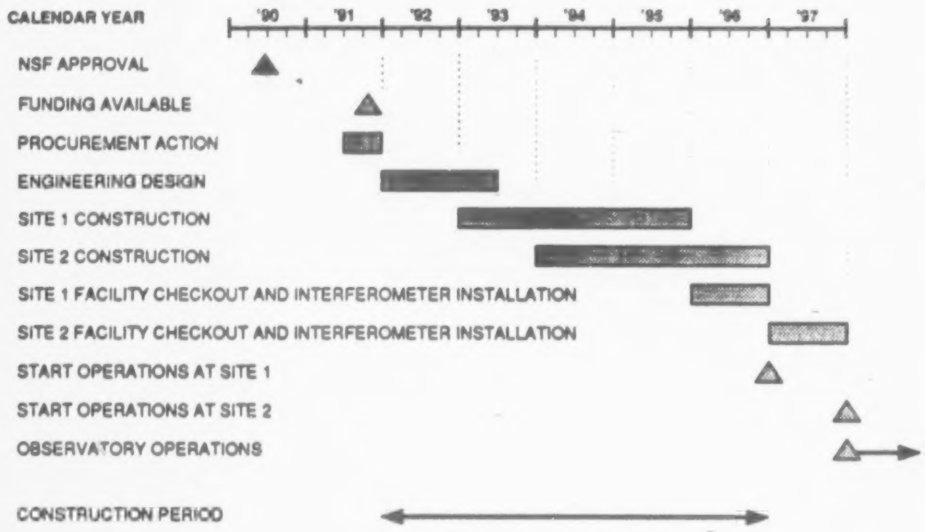
ATTACHMENT B

LIGO PROJECT MILESTONES

70's	Feasibility studies and early work on laser interferometer gravitational-wave detectors
1979	NSF funds Caltech and MIT for laser interferometer R&D
	•Deslattes Committee (NSF) endorses interferometers
1981–83	Design studies for long baseline interferometers
12/83	•Presentation to NSF Physics Advisory Committee
	•Presentation to Wilkinson Subpanel of National Academy of Sciences (NAS) Physics Survey Committee
3/84	•Presentation to National Science Board (NSB)
	NSB approves LIGO planning and feasibility studies
1984–87	Caltech/MIT/JPL design study for LIGO
7/84	•Presentation to President's Science Advisor
11/84	Caltech/MIT Memorandum of Understanding to establish joint project
	•Presentations to NSB and OMB
1986	International Society of General Relativity and Gravitation endorses LIGO
	NAS Physics Survey endorses LIGO
11/86	•NSF Cambridge Review Committee endorses LIGO
2/88	•NSF Review and Site Visit of LIGO project
10/88	•Presentation to NSF Physics Advisory Committee
12/89	LIGO Construction Proposal to NSF
2/90	•NSF Review and Site Visit of LIGO project
5/90	**NSB approves LIGO Construction Proposal**
1990	•Presentations to NAS Astronomy Survey Committee
10/90	•Presentations to NSB
	NSB approves Site Selection Process

ATTACHMENT C

LIGO PROJECT SCHEDULE



Mr. BOUCHER. Thank you, Dr. Vogt.

Dr. Will, we will be happy to hear from you.

STATEMENT OF DR. CLIFFORD M. WILL, PROFESSOR OF PHYSICS, MC DONNELL CENTER FOR THE SPACE SCIENCES, DEPARTMENT OF PHYSICS, WASHINGTON UNIVERSITY, ST. LOUIS, MISSOURI

Dr. WILL. Thank you, Mr. Chairman. I am Clifford Will, from Washington University in St. Louis. I am grateful for the opportunity to speak on the scientific importance of the LIGO project.

During the past 30 years, the subject of general relativity has experienced an extraordinary renaissance. Before this time, the subject was a highly mathematical, sterile endeavor, cut off from the main stream of physics and astronomy. The reason was a virtual absence of experiment. But since 1960, an intense program of experimental testing of general relativity and the development of gravitational wave detectors have helped fuel the flowering of this fundamental subject.

Another aspect of its growth has been the increasing contact between relativity and astronomy and astrophysics. Today I feel the field has reached an important stage when the choice is to continue this powerful advancement of experiment and theory, which is so important in every science, or to return to the theoretical sterility of the past. I believe that gravitational wave astronomy, LIGO in particular, form the key to progress on this front of knowledge.

Let me illustrate this by describing briefly some of the sources of gravity waves which LIGO will be able to study. Because gravity waves interact so weakly with matter, they pass virtually unimpeded through any material they encounter. Thus gravity waves formed deep inside the collapsing core of a supernova propagate freely to earth and thereby provide important information about the conditions in the core and the fate of the collapse. Ordinary light and other forms of electromagnetic radiation cannot penetrate the surrounding matter.

In addition, gravity waves are generated in regions where the very fabric of space-time is being bent and curved the most, such as near and around a black hole. Thus, gravity waves provide unique information about the most extreme and cataclysmic conditions in the universe.

Among the sources of gravitational waves LIGO will be able to detect are supernova collapses. LIGO will have the sensitivity to see supernova collapses far enough away to include the thousands of galaxies in our neighborhood of the universe, thereby giving it a rate of events that will provide a reasonable flow of data. LIGO will also have an important payoff for conventional astronomy. Because gravity waves are emitted some hours before light escapes from the supernova, an international array of at least three LIGOs will be able to pinpoint the direction of the incipient supernova, and will be able to direct light wave astronomers to that spot in the sky, enabling them to follow the light right from the start.

Coalescing binary systems are double star systems of neutron stars, or black holes, that have lost so much energy through prior gravity emission that they are closely orbiting each other, say 100 times per second, before a last burst of gravitational waves and a violent coalescence to a single object. Observing such a phenomenon will tell us, for example, how bodies move in strongly curved space-time, how matter behaves in relativistic tidal force fields, and possibly how black holes form.

These are all fundamental questions in relativistic physics. Part of my own theoretical research, for example, tries to determine in some detail what general relativity actually predicts for this coalescence phenomenon.

The processes in which black holes are formed leave the hole in a distorted state, like a bell struck by a hammer, the hole will vibrate and emit gravity waves at a characteristic frequency. Detection of this unique radiation may provide the first smoking gun for the existence of black holes. This would be striking confirmation of one of the most important predictions of Einstein's general relativity theory.

The observation of any of these phenomena or others which I have not mentioned, would lead to a fundamental new understanding of the universe. But more significant will be the discoveries of things which are not on this or any list. Although theorists are confident of their estimates of the sources, and the LIGO team is confident they can reach the needed sensitivity, success is certainly not guaranteed.

It is true that there are risks. Risk is inherent in being at the forefront of science or any field. The scientist who takes no chances is the one working on pedestrian problems of marginal benefit. The politician who desires no risk is the one who decides not to run. The nation that does not take chances is the one that watches history pass it by.

When you weigh the rather modest risks inherent in LIGO against the enormous potential for fundamental, ground- breaking knowledge about space-time and the universe, I believe you will agree that LIGO should be approved and funded.

Thank you very much.

[The prepared statement of Dr. Will follows:]

TESTIMONY AT THE AUTHORIZATION HEARING OF THE SUBCOMMITTEE ON SCIENCE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY U. S. HOUSE OF REPRESENTATIVES

Washington D. C. March 13, 1991

Clifford M. Will
Professor of Physics
McDonnell Center for the Space Sciences, Department of Physics
Washington University in St. Louis

Thank you for giving me the opportunity to testify on behalf of LIGO, the Laser Interferometer Gravitational-Wave Observatory. I am not directly involved in the project, and am not even an experimental physicist, so that I am reluctant to comment on the laboratory achievements made to date or on the challenges yet to come. Rather, I am a theorist in general relativity and astrophysics, and have come to speak to the fundamental importance to astronomy and physics of this observatory. The main points that I would like to make are these:

LIGO is an opportunity to open a new window on the universe, which will make new and fundamental discoveries.

LIGO follows the classic traditions of science: it will make discoveries that will challenge accepted theories; new theoretical insights will lead to further observations whose results will pose new challenges, and so on. At each stage, we will reach a higher level of comprehension of the universe.

LIGO will become part of an international network of observatories which will have the capability of pinpointing sources of gravitational radiation, allowing coordinated observation by a range of astronomical techniques of violent cosmic events.

LIGO is not merely a way to verify Einstein's theory of general relativity, although it will check the basic nature of gravitational radiation. A 30-year program of relativity experimentation has already led to dramatically improved confidence in Einstein's gravitation theory.

LIGO is not merely a detector of gravitational waves. The existence of gravitational waves has already been confirmed to a high degree of confidence by observations of the shrinkage of a binary pulsar orbit.

Before addressing each of these points, let me review briefly the significance of gravitational waves and the history of gravity-wave research.

BACKGROUND

Gravitational radiation is a subject that is almost as old as general relativity itself. In 1916, shortly after completing the final formulation of the general theory, Einstein succeeded in showing that the field equations of general relativity admitted wavelike solutions analogous to the familiar light waves of electromagnetic theory. For example, a rotating dumbell will emit gravitational waves. The waves carry energy away from the rotating dumbell, just as electromagnetic waves carry energy away from a light source. That was about all that was heard on the subject for over 40 years, primarily because the effects associated with gravitational waves were extremely tiny, unlikely (it was thought) ever to be of experimental or observational interest. Certainly, the waves emitted by a rotating dumbell are too weak *ever* to be detected.

But in 1968, the idea of gravitational radiation was resurrected by the stunning announcement by Joseph Weber of the University of Maryland that he had detected gravitational radiation of extraterrestrial origin using massive aluminum bars as detectors. A passing gravitational wave acts as an oscillating gravitational force field that alternately compresses and extends the bar in the lengthwise direction. However, subsequent observations by other researchers using bars with sensitivity better than Weber's failed to confirm Weber's results. His results are now generally regarded as a false alarm, although there is still no good explanation for the "events" that he recorded in his bars.

Nevertheless, Weber's experiments did initiate the program of gravitational-wave detection, and inspired other groups to build better detectors. Currently, many laboratories around the world are engaged in building and improving upon the basic "Weber bar" detector, some using bigger bars, some working at room temperature, and some working near absolute zero degrees. The goal in all cases is to reduce noise from thermal, electrical and environmental sources as much as possible in order to detect the tiny oscillations produced by a gravitational wave. Many of these bar detectors are on the air, and represent an important component of gravitational wave searches.

In the long run however, the best sensitivity for detecting gravitational waves will be achieved by laser interferometry, as envisioned by the LIGO project. Laboratories in Europe and Australia are also working on interferometer systems. Light from a laser is split into two beams which travel along two perpendicular arms, are reflected back and recombined at the starting point, where they can cause constructive or destructive interference. A passing gravitational wave will change the length of one arm of the apparatus relative to the other, and cause the interference pattern to vary. Professor Vogt's testimony describes LIGO in more detail.

GRAVITATIONAL WAVES: A NEW ASTRONOMICAL WINDOW

What is the nature of the discoveries that await gravity-wave astronomers? Because gravity waves interact so weakly with matter, they pass virtually unimpeded through any material they encounter. Thus gravity waves formed deep inside the collapsing core of a supernova propagate freely to Earth and thereby provide important information about the conditions in the core and the fate of the collapse. Ordinary light and other forms of electromagnetic radiation cannot penetrate the surrounding matter. In addition, gravity waves are generated in regions where the very fabric of spacetime is being wrenched and curved the most, such as near and around a black hole. Thus gravity waves provide unique information about the most extreme and cataclysmic conditions in the universe.

From what we have learned about the nature of stars and galaxies from other branches of astronomy, we astrophysical theorists have identified a number of promising sources of gravitational waves that LIGO will be able to detect. Among them are:

Supernova core collapses: In a galaxy like ours, a supernova like the one in 1987 is a rare event. LIGO will have the sensitivity to see supernovae collapses far enough away to include the thousands of galaxies in our neighborhood of the universe, thereby giving a *rate* of events that will provide a reasonable flow of data.

Coalescing binary systems: These are double-star systems of neutron stars or black holes that have lost so much energy through prior gravity-wave emission that they are closely orbiting each other 100 times per second in a final dance of death before a last burst of gravitational waves and a violent union to a single neutron star or even a black hole.

Black-hole vibrations: Most processes in which black holes are formed leave the hole in a distorted state; like a bell struck by a hammer, the hole will vibrate and emit gravity waves at a characteristic frequency. Detection of this unique radiation may provide the first "smoking gun" for the existence of black holes.

The observation of any one of these events would lead to fundamental new knowledge about the universe. But more significant will be the discoveries of things which are not on this or any other list. For as confident as theoreticians are, they are notoriously poor at predicting the future discoveries in their fields. Even their current theories about the sources listed above could be way off the mark. This is how it has been throughout 20th century astronomy, during which several new observational windows on the universe have been opened. In each case, surprising new discoveries were made. The table below illustrates some of these new astronomies and just one surprise (of many) from each.

Astronomical Window	Surprising Discovery
Radio astronomy	Quasars, the most distant and powerful sources of energy known, still only poorly understood.
Infrared astronomy	The Cosmic Background Radiation, our most precisely known relic of the big bang
X-ray astronomy	X-ray source Cygnus X-1; probably contains a black hole
Neutrino astronomy	Solar Neutrinos, still a major unsolved problem for astronomers and particle-physicists alike
Gravity-wave astronomy	?

AN OPEN ENDED OBSERVATORY

Although the first observation of a gravitational wave will be a moment of high drama and excitement (and may well lead to a Nobel Prize), it will really be only the beginning. The purpose of LIGO is to use gravitational waves as a probe of the inner workings of the exotic sources described above. It will undoubtedly uncover things we don't understand. It will thus lead to new theoretical work to try to clear up the new mysteries. This work may suggest new observations by optical, radio, X-ray or neutrino astronomers to provide additional evidence. This in turn may lead to new kinds of gravity-wave observations, and so on. The fruitful cross fertilization between branches of astronomy that now exists will be extended into the gravitational realm. Furthermore, the active interplay between gravitation theorists and gravitational-wave observers will be a central aspect of the endeavor.

AN INTERNATIONAL NETWORK

LIGO will ultimately be part of an international network of gravitational-wave observatories. Because gravity waves are so weak, at least two widely-separated detectors are needed in order to distinguish a gravitational wave of extraterrestrial origin from the inevitable noise present in each detector. This is the reason why LIGO involves two separate installations. Furthermore, unlike a telescope, for instance, which can pinpoint a source of light in the sky, a single gravity wave antenna is only weakly sensitive to the direction from which the wave is coming. However, an array of at least three detectors around the world, can, by monitoring the small differences in arrival-time of a gravity wave signal in the different locations, determine the location of the source on the sky (four are required to determine it uniquely). This will be of great importance in studying supernovae, for example. Since the gravity waves are expected to be emitted from the collapsing core some hours before the brightest light is emitted from the surrounding gas, they will be the first to arrive at Earth. Thus an international network of gravity-wave astronomers could pinpoint the location of a supernova, and direct their optical, Xray and Gamma-ray colleagues toward that region of the sky in advance of the light output.

So central is this concept of a worldwide network of gravity-wave observatories, that in 1986, the International Committee on General Relativity and Gravitation, headquartered in Bern, Switzerland, and representing the world's researchers in gravitation, issued the following resolution:

> "The International Committee on General Relativity and Gravitation strongly endorsed the plans, in the German Federal Republic, France, the United Kingdom and the United States, for kilometer-scale laser-interferometer gravitational-wave detectors. These detectors show great promise both of testing key aspects of the fundamental laws of gravity, and of opening a revolutionary new window onto the astrophysical universe."

The importance of an array of at least three detectors cannot be overstressed. In addition to the ability to pinpoint the source, the added capability to identify weak signals by simultaneous observation in three separated detectors means that the volume of space which can be observed is roughly doubled.

The LIGO proposal is for two detectors in the United States. There are British-German and French-Italian proposals for two detectors in Europe. Proceeding with two U.S. detectors independently of developments in Europe has several important advantages:

(1) With two detectors under the same management, correcting problems, coordinating observing schedules, and making improvements is significantly more efficient.

(2) A single installation is ineffective as a detector of gravitational waves because of the inability to distinguish a gravity-wave signal from local noise. Thus it is not desirable to build one U.S. installation and one in Europe, for a failure of either side to achieve the sensitivity goal in a timely manner would mean that essentially no useful science could be done.

NOT PRIMARILY A TEST OF EINSTEIN'S THEORY

LIGO is not intended to test Einstein's general theory of relativity. During the past 30 years an intense international experimental effort has gone into performing high-precision tests of the predictions of Einstein's theory of gravity using modern technology such as atomic clocks, lasers, spacecraft tracking, radio telescopes, laboratory techniques, and so on. The theory has passed every test with flying colors. Although LIGO could check certain aspects of the nature of gravitational waves (such as whether or not they propagate with the same speed as light), such tests are really secondary to the astronomical mission of LIGO

NOT A TEST OF THE EXISTENCE OF GRAVITATIONAL WAVES

The primary goal of LIGO is not to verify the existence of gravitational waves. That question has already been answered, albeit indirectly, using a double-star system known as the Binary Pulsar. Discovered in 1974, it consists of a pulsar (which is a rapidly spinning neutron star) orbiting a companion neutron star once every eight hours. Like a rotating dumbell, an orbiting binary system should emit gravitational radiation, and in the process lose some of its orbital energy. This energy loss will cause the pulsar and its companion to spiral in toward each other. By studying the motion of the pulsar, radio astronomers have determined that the orbit is indeed shrinking at a rate that matches to better than one percent the rate predicted by general relativity. This confirms the existence of gravitational radiation and the general relativistic equations that describe it. This understanding of the foundations of gravitational radiation gives us confidence that we can now begin to use gravitational radiation as a probe of the nature of the sources.

AUTOBIOGRAPHICAL SKETCH - CLIFFORD M. WILL

Clifford Martin Will is Professor of Physics, and member of the McDonnell Center for the Space Sciences at Washington University in St. Louis. Born in Hamilton, Canada in 1946, he received his pre-college and college education there, obtaining a B.Sc. in Applied Mathematics and Theoretical Physics from McMaster University in 1968. In 1971, he obtained a Ph.D. in Physics from the California Institute of Technology in Pasadena, and remained at Caltech for one year as an Instructor in Physics. He was an Enrico Fermi Postdoctoral Fellow at the University of Chicago from 1972 to 1974. In 1974 he joined the faculty of Stanford University as an Assistant Professor of Physics, and remained there until 1981. From 1975 to 1979, he was an Alfred P. Sloan Foundation Fellow, and during 1978-79 a Mellon Foundation Junior Faculty Fellow. In 1981 he joined Washington University in St. Louis as Associate Professor, and in 1985 became Professor of Physics.

He has published over 100 scientific articles or abstracts, including 6 major review articles, 12 popular or semi-popular articles, and two books, including *Theory and Experiment in Gravitational Physics* (Cambridge University Press, 1981), and *Was Einstein Right?* (Basic Books, 1986). The latter book won the 1987 American Institute of Physics Science Writing Award, and has undergone translation into French, German, Italian, Japanese, Portuguese, and Spanish. In 1986 he was selected by the American Association of Physics Teachers to be the 46th annual Richtmyer Lecturer and in 1989, he was elected a Fellow of the American Physical Society. He was Chairman of the Committee on Accuracy of Time Transfer in Satellite Systems (Air Force Studies Board, National Research Council) from 1984 to 1986. He is currently a Divisional Associate Editor for *Physical Review Letters*, and is a member of the Resource Letters Editorial Board of the American Association of Physics Teachers, the Space Science Working Group of the Association of American Universities, the Science Coordinating Committee for Experimental Gravitation of NASA, the Committee on Fundamental Constants and Basic Standards of the National Research Council, the Editorial Council of *Annals of Physics*, and the Introductory University Physics Project. His research interests are theoretical, encompassing the observational and astrophysical implications of Einstein's general theory of relativity, including gravitational radiation, black holes, cosmology, the physics of curved spacetime, and the theoretical interpretation of experimental tests of general relativity.

Mr. THORNTON. Thank you very much, Dr. Will.

Dr. Tyson, we will now hear your testimony.

STATEMENT OF DR. J. ANTHONY TYSON, PHYSICS RESEARCH LABORATORY, AT&T BELL LABORATORIES, MEMBER, NSF ADVISORY COMMITTEE FOR ASTRONOMICAL SCIENCES

Dr. TYSON. Thank you, Mr. Chairman. I am Tony Tyson from Bell Laboratories. I have spent most of my career as an experimental physicist and astronomer, trying to measure tiny things in the presence of confounding noise.

Dr. Will just gave a very nice review of the kinds of things I think the astrophysical community feels would be very beneficial to measure with a big gravity wave observatory, perhaps like an operating LIGO. There has been quite a lot of debate, I must tell you, within the astrophysical community, on whether LIGO in any of its phases could realistically detect any of these sources. Part of it is due to the projected sensitivity of LIGO and part of it is due to the unknown scenarios by which these events actually occur.

For many years, gravitational wave astronomy was justified, or gravitational wave detector development, was justified because of the physics that one might learn from the detection of some very interesting gravitational radiation from a known object, so that one can go out and actually check Einstein's projected relationship between the motion of the mass and the amount of gravity waves emitted. To a very large extent, that beautiful experiment has now been done by Professor Joe Taylor at Princeton, and his colleagues, in a kind of gravity wave antenna in which one actually has a pair of neutron stars that are looked at.

So if one is to sell LIGO to the scientific community, particularly to the astronomical community, one has to sell it on the basis of the astronomy. There are these doubts, and we can perhaps go into them later, of how much radiation would be emitted. There is one source, however, that we know exists, and that is a pair of neutron stars that are falling into one another in the final moments of their collapse and merger. One can actually calculate how much gravitational radiation to expect, and you sort of know how many of those are out there.

I think LIGO, in its most reasonable extrapolation, falls slightly short of being able to detect these. That is no argument, however, against LIGO. I think it is an incredibly interesting adventure, like the opening of the radio window or the x-ray window or any other new window in astronomy. If a gravitational wave observatory eventually gets operating, I think it would be very significant. It is a possible new window. I don't think we are assured of a rich harvest.

How important scientifically are the possible detections? There have been similar discoveries of equal importance made fairly routinely over the past few decades, with $5 million to $50 million facilities in astronomy. Gravitational waves are not like shining stars, you can't point a telescope at them to detect them. You develop new instrumentation and study them. It is more like a flash, a thing that goes bump in the night. We don't know when it will occur. It might be next year. It might be in 30 years. It is a very tiny force. I think the LIGO team has done an incredibly good job of developing and using current high technology in pushing this kind of detector. They are way ahead of where we were in the mid-1970s in terms of detection.

The major cost of scaling up the LIGO prototype to a four-kilometer machine, which is this proposal, is in fact in the bricks and mortar. When I say bricks and mortar, I must include the vacuum system. The question is whether there are any showstoppers in the prototype. In my judgment, there probably are. There is an undiagnosed source of noise that has been around for some time now in the prototype, and I think it is probably premature to scale up the prototype to four kilometers at this time. I think I would probably research this particular source of noise and try to get rid of it before scaling up the prototype. I regret to say that I think it is premature at this time.

Suppose eventually the source of noise is found and fixed, and one scales it up to four kilometers and it has a hundred times more sensitivity, you have ten times more power from the laser. Will the resulting thousand times more sensitivity give an observatory a tool useful for astronomical data collection? You have to have really quite a few of these spread around the world to have an observatory, assuming it works. At least two, probably more like three, of these big facilities, spaced around the world, would be required.

There are other sources besides these neutron stars. I think we would be lucky, and I think the astrophysical community feels we would be lucky to find them.

After being notified that I should appear here, I conducted an opinion survey of the astronomy community. This was a biased survey, I must tell you. I selected 60 names of people who I thought would be users of LIGO, from within the astronomy community. So it was biased in favor of LIGO in some sense. These were people who had thought deeply about these issues.

The ratio was four to one against, for a variety of reasons, mostly because of these issues of unknown source. Astrophysicists are quite a lot more sophisticated now than they were back in 1932, when radio was available but not taken up by the astronomy community. I think people think a lot about these things, and that is probably most responsible for this ratio.

There are other priorities as well in science. The large facilities one has in physics and engineering, for example, $200 million to $400 million facilities, have thousands of users. There are perhaps 10,000 experiments performed yearly in some of these big facilities. Thus, one has to talk about big science versus little science.

I must sum up by saying that it is extremely important for physics and astronomy that LIGO technology development continue.

[The prepared statement of Dr. Tyson follows:]

Testimony of
Dr. J. Anthony Tyson

Optical Physics Research Department
Physical Research Laboratory
AT&T Bell Laboratories

Before the
Subcommittee on Science
of the
Committee on Science, Space, and Technology
United States House of Representatives
March 13, 1991

I. Gravitational Radiation Search

The proposed LIGO (*Laser Interferometer Gravitational Wave Observatory*) builds on 22 years of attempts to observe gravitational waves, and 75 years of gravitational theory. At $211M, the cost of this facility is over twice the total 1991 NSF Astronomy budget, and half the NSF physical sciences budget. In this testimony I hope to give an impartial expert review of the chances for success of LIGO and my judgement of the scientific leverage (science per dollar), including its possible impact on US technology and scientific human resources. I also include the results of an informal poll of the US astronomical community. First, I must briefly review the exciting story of dynamic gravity and its relation to physics and astronomy.

i. Physics

Newton showed us that masses interact via a mysterious force called gravity. Seventy five years ago Einstein published his general theory of relativity, in short, a theory of gravity. He describes gravity as a warping of space-time. This warp is not necessarily constant. Move mass around and you change the warp. Changes in the warp propagate outwards (gravitational waves) like a ripple on a pond.

We are all familiar with electromagnetic radiation: light, radio, and microwaves, for example. Gravitational radiation is something completely different, as different as an ocean wave is from a light wave. Gravitational radiation represents waves in the very fabric of space-time. These strange waves are generated during certain fast accelerations of massive objects. Because the force of gravity is so much weaker than the electromagnetic force (atoms are held together by electrical force, not gravity) gravitational waves are incredibly weak. It is hopeless to attempt to generate gravitational waves in the laboratory: a 500 ton steel bar, spinning nearly to the breaking point, would produce an effect of only one part in '1 followed by forty zeros' (10^{40}) in a nearby detector. Mass densities characteristic of black holes or neutron stars (solid nuclear matter) and velocities approaching the velocity of light are required. Einstein's theory predicts a relation between the motion of masses and the strength of the gravity waves which are radiated.

II. Detection

The effect of a passing gravitational wave is a momentary change in the apparent distance between two points. The strength of the wave may be expressed as a fractional change in length of any object. These waves therefore can in principle be measured by uncommonly accurate metrology. Another consequence of the weakness of gravity is that gravitational waves with any hope of detection are generated only by the most violent events in our universe: the sudden collapse of a star to a tiny object; two black holes spiraling into each other; the unimaginable turbulence at the birth of the universe, the Big Bang.

There is an unfortunate further consequence of the weakness of gravity compared with electromagnetism: most of these violent astronomical events produce much more detectable radio and light than detectable gravitational waves. It is much easier to detect light or radio waves from a quasar billions of light-years distant than it is to detect gravitational waves from whole stars falling into the massive black hole in the heart of the quasar. If we are lucky and gravitational waves from violent massive events are eventually discovered, they may tell us something about physics in the warped space-time near the black hole. They may also signal the existence of other violent events of relevance to astronomy and our understanding of the processes by which the universe as we know it was built. But other astronomical observations of the source will be necessary in order to get much science out of any gravitational wave detection.

What are we hoping to learn? For many years a central justification for the gravitational wave searches was the possibility that we might detect waves from a known object, and thus be able to check Einstein's prediction. This *physics* experiment has recently been achieved by another experiment which I describe below. Thus if we are to justify LIGO scientifically, it must be in terms of the *astronomy* is could produce: the possible discovery of violent events, such as mergers of compact massive bodies, observable in perhaps no other way. We must ask another question: *how realistic is this hope*? In particular, how realistic are the projected sensitivity of LIGO and the theoretical estimates of the violent sources? In short: is it realistic in the next few years to call LIGO an astronomical observatory?

We must discuss the state-of-the-art in gravitational wave detection and what we know about violent sources that can and cannot be out there. First I summarize the theoretical estimates for sources. The maximum strengths of gravitational waves predicted at Earth range from one part in one billion trillion to less than one part in one thousand trillion trillion (10^{27}) fractional change in length. Even with ingenious schemes and state-of-the-art technology this is difficult or down right impossible to measure. It is also difficult for us to contemplate how small a change that represents. The following example may help us grasp the magnitude of the task. Imagine this distance: travel around the world 100 billion times (a total of 2400 trillion miles, or one million times the distance to Neptune). Take two points separated by this total distance. Then a *strong* gravitational wave will briefly change that distance by less than the thickness of a human hair. We have perhaps less than a few tenths of a second to perform this measurement. And we don't know if this infinitesimal event will come next month, next year, or perhaps in thirty years.

iii. First Successful Observation

The existence of gravitational waves has recently been confirmed and accurately measured in an ingenious radio astronomy observation. Joseph Taylor (Princeton) and collaborators have been looking at a pair of neutron stars for fourteen years. These neutron stars are in close orbit about one another, and one of them is the radio pulsar 1913+16. This binary system loses energy by emission of gravitational radiation, gradually spiraling into an eventual merger. Its orbit can be accurately measured by the radio pulses from the pulsar.

Their data confirm Einstein's theory of gravitational wave energy loss in the strong gravity of the pair of neutron stars to an accuracy of 1%. This is a truly outstanding achievement. (It is worth noting that LIGO would not be sufficiently sensitive to detect gravitational waves from this neutron star binary). Moreover, new pulsars suitable for low frequency gravitational wave studies have been recently discovered. By observing the tiny changes in path length to these separate pulsar systems, observations are now underway of cosmic background gravitational wave "noise". These are perhaps the most fundamental kind of gravitational waves, possibly originating in the Big Bang. In my view they are the most likely kind of gravitational waves to be of astrophysical value, since there is a lot we do not know about the origin of our universe.

However, some types of violent massive gravitational events cannot be detected by pulsar timing. Examples are asymmetric core collapse of a dying star in a supernova explosion, and the final death spiral of a pair of neutron stars. These violent events would emit gravitational waves at the comparatively high frequency range 100-1000 Hz.

iv. LIGO

Since 1969 the technology of gravitational wave detection in the 100-1000 Hz range has advanced a factor of one hundred, to a sensitivity to fractional change in length of one part in one billion billion. By any criterion this is an outstanding achievement in technology development. Unfortunately this current sensitivity is still over *ten thousand times less* than required to reliably detect the strongest hypothesized sources of gravitational waves. [In terms of energy sensitivity this is one hundred million times short of reliable detection]. Every factor of ten increase in sensitivity at this point corresponds to very hard work requiring major breakthroughs in technology. The *hope* is that LIGO, through a combination of new technologies (innovative use of lasers, super-reflective mirrors, and future advances in vibration isolation), will ultimately bridge this large gap in sensitivity. It will not be easy, and is not a sure thing.

v. Astronomy

Suppose LIGO works eventually. What is the relative scientific importance of these possible observations? Observations of violent events *may* reveal a new class of compact object. More likely, detection of weak gravitational events would enhance our understanding of the number and fate of known compact objects like black holes and neutron stars. But identifying what was detected, and it's location on the sky and distance may be quite difficult. This is comparable to the state of development of radio astronomy in 1932, but with no hope of similar technological spin-offs (i.e. no equivalent of TV, VCR, etc).

A discovery by LIGO of violent events involving massive objects would rank with analogous major discoveries which have been made frequently using large radio and optical telescopes or other detectors ($5M - $50M facilities). Examples are: discovery of neutron stars ("pulsars"); discovery of neutrinos (penetrating particles originating in the core of the collapsing star) from supernova 1987A; discovery of dark matter; discovery of black holes; discovery of compact dark matter by gravitational mirage; discovery that quasars are intensely luminous cores of galaxies; discovery of jets from active galaxies. Except that it will be difficult, even if detected, to get useful astrophysics from the LIGO data. The ultimate scientific importance for our basic understanding of the dynamics of massive objects in our universe will hinge on how these initial detections are followed up with larger gravitational wave observatories which might eventually study these kind of events (if detected) in detail. These real laser interferometer gravitational observatories are perhaps decades away.

What is the opinion of the US astronomical community? I have conducted an informal poll of 60 astronomers in the US who I suspected have thought about LIGO and who are not conservative in the sense that they have a track record of striking out in new directions. Here are some representative responses: "the sources we think we know are out there are too weak to be detected in gravity waves by LIGO." "LIGO is at best a physics experiment, not an astronomical observatory." "... astronomers can think of cheaper experiments that are much more likely to yield fundamental advances." Some support LIGO as a test-bed for technology development (unrelated to astronomy). Most feel that the gravitational wave strengths and rate of occurrence of hypothesized sources have been overestimated in the past. As an astronomer I generally concur. It is premature to call LIGO an observatory in the sense that astronomically important data will probably not come out of "EARLY LIGO" (this $211M proposal). As a physicist I am fascinated by this experiment and would like to see much of it funded, but not at the expense of hundreds of individual principal investigator grants and other smaller major initiatives in physics and astronomy.

II. Required Technology Developments for Useful LIGO

It is important to define what version of LIGO we are talking about. I shall discuss only the "EARLY LIGO", which *if successful* would have to be 1000 to 10,000 times more sensitive (depending on which frequency) than the current LIGO prototype. [I see no clear path of technology development which can assure a successful "ADVANCED LIGO", and so will confine my comments to the "EARLY LIGO", hereafter simply referred to as "LIGO"].

As such, LIGO demands a truly phenomenal increase of sensitivity, demanding new techniques in several areas of optical and mechanical technology. Although some of these technologies have been under development with the LIGO prototype, these developments in my judgement are not sufficiently advanced to assure operation of LIGO at astronomically useful sensitivities. More documented advances, published engineering results, and demonstrated performance are required. I support a measured LIGO research program including milestones, not for astronomy, but for technology development.

A ten thousand fold increase in sensitivity over present impressive levels is required in order to detect even the strongest hypothesized gravitational radiation events thought to occur more than once per year. The death spiral of a binary neutron star system would have a characteristic gravitational wave "signature", but one must go out to encompass enough galaxies (300 million light years distant) to find enough of them to give more than one of these events per year. The resulting signal at Earth would still be ten times too weak to be reliably detected by LIGO even if 10,000 times more sensitive than the LIGO prototype. Other violent events which *would* possibly be detected by LIGO are known to be rare: in February 1987 a massive star, a mere 175,000 light years distant, underwent core collapse. The resulting explosion of its outer layers was visible to the un-aided eye (supernova 1987A) and, significantly, a burst of neutrinos (from the core) was detected at two sites on Earth. This core collapse might have been detected by a LIGO *if the core pancaked during collapse*. The last supernova this bright was seen several hundred years ago. Accounting for non-visible events of this type in our local neighborhood might move the rate up to one per thirty or fifty years. This is not very encouraging for LIGO.

In no sense could a single LIGO be called an astronomical "observatory". This is because several high sensitivity LIGOs, spaced around the Earth, are required to unravel the information in the complex gravitational wave signature. Even then, additional information about the source would probably be required. A single LIGO cannot tell what direction in the sky an event came from, and also has great difficulty discriminating against local interference. This is therefore a natural project for international cooperation. The Germans and Italians are working on the design of very similar detectors. Noise in the LIGO detector, like static on your radio, can prevent detection. Each of these LIGOs must be sufficiently sensitive *and low noise* to reliably detect the astronomical event. There are a few hypothesized astrophysical sources which might give events detectable by LIGO (discussed above), but they are thought to be rare. Are these theoretical estimates for the *sources* of gravitational waves reliable?

Most astrophysicists feel that the estimated strength of the hypothesized sources is optimistic. In my opinion, a factor of 100,000 improvement over the present sensitivity would be required to achieve an astronomically useful detector. For violent "burst" sources of the types discussed already, this would correspond to a length sensitivity of one part in a billion trillion (10^{21}) at frequencies of a few hundred Hz, at 90% confidence. Other types of weaker sources of gravitational waves (like spinning non-spherical neutron stars) give more of a continuous tone signal. The LIGO group has thought of clever ways to sensitively tune LIGO to a given frequency, but these techniques have not yet been demonstrated with the LIGO prototype. [Sensitivities of one part in 10^{26} or better are required in this latter case].

III. Is it possible?

How can this giant advance in sensitivity over the LIGO prototype be achieved? A factor of 100 may be achieved by scaling up the size to 4km as planned. That accounts for much of the requested $211M. Another gain of up to 10 over the present scheme will probably be obtained by recycling the laser light or going to a higher power laser. Another hundred fold increase in sensitivity beyond this would be required to reach the above goal for LIGO. Even this initial factor of 1000 increase in sensitivity will be ineffective unless the vibration isolation is substantially improved. This is a crucial point. A factor of *ten million* improvement in noise (at a frequency of 100 Hz) of LIGO over that of the prototype must be obtained. Since this development could be done on the LIGO prototype, many physicists feel that this should be demonstrated and documented before embarking on a full-scale LIGO. In particular, the factor of ten improvement of sensitivity mentioned above (laser power) could be demonstrated with the existing LIGO prototype, given adequate noise reduction.

The additional factor of 100 increase in sensitivity is not assured, and would have to await future developments. A single 4km LIGO facility would be required to pursue this further difficult development program. *In summary, even if all the estimated improvements over the LIGO prototype are achieved in LIGO, the resulting sensitivity of LIGO falls at least ten times short of being useful astronomically.*

IV. Science per Dollar

Had supernova 1987A been detected in gravitational waves by a LIGO would we have derived as much science as we did by the detection of 1987A's neutrinos? Possibly. But a world-wide network of LIGOs would have been required. And the collapsing core of the supernova would have had to "pancake" in its final moments, to give a detectable signal on Earth. The neutrino detection facility cost $5M, and was built to do a different physics experiment. The burst of neutrinos from 1987A was gravy. This raises the question of science per dollar.

Other large facilities in physics and engineering (mostly funded by DOE) with price tags of $200M to $600M have large user communities, typically over 1000 scientists. In astronomy, our National Observatory currently has two 4-meter telescopes (built 20 years ago at $20M each) with a user community of over 700 astronomers. This proposed LIGO, at $211M, has four scientists. Some astronomically useful version of LIGO perhaps a decade hence might begin with around 20-100 users. In this connection we must discuss the health of US science.

Due to advances in technology in recent years, the physics and astronomy supported by the National Science Foundation is on the verge of major breakthroughs in several areas. In these cases we know from other experiments or observations that the science is there for the taking: we just have to get on with the exciting business doing the research, building the equipment required, and performing the new experiment or observation. There are plenty of examples in astronomy and physics and other fields of this kind of threshold science. Yet the required funds for these relatively modest facilities $1M - $60M have been difficult or impossible to raise. Meanwhile, the Europeans and Japanese are taking leadership in several key areas of relevant technology.

i. Innovation in US Science and Technology

Innovation in technology development and fundamental research in science are closely coupled. It is therefore disturbing to see a decline in risk-taking in US science. This unfortunately natural trend towards "safe" science (assured results) occurs in times of tight fiscal constraints. This trend is more intense in individual PI grants than in "big" initiatives. To be assured of success in the grants competition you, increasingly often, must show that your research will produce assured results. New unproven gadgets or unexplored directions and technologies are naturally avoided. Yet small science continues to be the backbone of US technology development and manpower. LIGO is an important example of risk-taking in big science. It is also exemplary of the rising costs of high technology. A healthy mix of innovative grant support and occasional risky major initiatives is needed.

For every example of risky big science there are hundreds of risky (potentially very productive) grant applications, in NSF physical sciences, which go unfunded primarily because they represent new directions and are necessarily speculative. Examples can be found in physics, biophysics, astronomy, medical physics, etc. Successful university scientists spend a large fraction of their time writing multiple grant applications and evaluating others, not pursuing research. Leon Lederman (Chicago) discussed this tragedy for US science in a recent address to the National Academy of Sciences: "My concern is for the future of science in the US and for the profound cultural and economic benefits that science brings."

Funding debates can become divisive, pitting one kind of science against another. A healthy science enterprise will encourage innovation in all fields. At some level, however, one must ask the question of efficiency, both in terms of science derived and technical manpower trained. In the face-off between big projects and individual investigator grants, it is often easier to sell the big projects because of their visibility. Yet individual research grants are the heart of our Country's resource for innovation and play a crucial role in the educational pipeline. We must strike a healthy balance between grants, centers, and national labs. In these times of declining real support in physics and astronomy all three are suffering. Congress sees the overall NSF budget going up. We scientists see grants drying up and national labs barely able to function. There is a trend toward less risk, and less discovery. This has downstream implications for US technology.

Innovation is not necessarily synonymous with a "shot in the dark", although risk-taking in fundamental science is crucial to its long term health. In my judgement we are doing more damage to innovation and the educational pipeline by declining forward-looking individual investigator grants applications (due to pressure on grants) than by postponing occasional big science projects. The education of graduate students and postdocs is severely affected by this. If you took $200M and parceled it out to the top 200 applicants in an "innovation" contest, I think you would be amazed to see the number of breakthroughs. The average grant in physics and astronomy and other fields is not currently sufficient to fund a postdoc, and often graduate students find themselves looking for part time support elsewhere. Many researchers have stopped applying to the NSF for funding altogether. The main reason I have stayed in industry in recent years rather than return to academia is this dismal outlook for innovative research at Universities.

V. Recommendations

It makes a lot of sense to develop the technologies required for a successful world-wide LIGO "observatory" in stages. In my judgement it is premature to commit to a full-scale LIGO (as proposed) before demonstrating the required technologies first on the existing prototype, and then on a single LIGO phase A facility ("half-LIGO"). There is no strong technical justification for building *two* LIGO facilities (this proposal) in the US at this time. Astronomers who have thought deeply about this issue generally feel that LIGO will be more useful as a vehicle for technology development and perhaps some physics, than for astronomy in the forseeable future.

The remarkable technology development work of the LIGO team should continue to be supported. It should be emphasised that *this technology development should go on.* As in other big science projects, LIGO should be part of an international collaboration. In fact, an eventual LIGO observatory of astronomical utility would have to be world-wide in scale. Two interferometer facilities, one in the US and one in Europe, would be a minimal requirement for an eventual gravitational wave observatory (considerable science would be sacrificed with only two interferometers)
-- but only after the necessary technologies have been developed and demonstrated.

In order to begin to reverse the pressure on individual PI grants in NSF basic science, I recommend that the NSF budget be increased appropriately and that these funds not be mandated for other programs outside NSF physical sciences. Regarding astronomy, the National Science foundation plays a critical and unique role in its efficient support of ground-based astronomy research.

Mr. THORNTON. Thank you very much, Dr. Tyson.

I am particularly interested in your suggestion that it might be appropriate to develop one such facility in order to detect and determine the feasibility of doing away with the noise. And I do want to ask Dr. Vogt to comment on that. I also want to just throw another illustration in, Dr. Vogt. Members of your university, working with members of an institution with whom I had an association until recently, developed a project for the Operation Grande, a neutron telescope peering through the mass of the world to observe the cause of the upward moving neutrinos that had traveled through the mass of the earth, screening out other particles that do not have that capability to penetrate, and impacting upon nuclei going upward and sending those upward through a water pit and a detection unit, to do about the same kind of thing, to determine the decay of neutrino stars.

I compliment your institution for being in the forefront in neutrino research as well as in gravitational waves. I hope you will carry that congratulations back to the people out there on your campus.

Dr. VOGT. Thank you, Mr. Chairman. It is one of the functions of Caltech, and always has been, to be in the forefront of development of new techniques. That happens to be one of our specialties.

Let me address the question of whether the building of a single LIGO would be advisable as an intermediate step. The reason this is not contained in my own game plan, and in the game plan of my own colleagues, is that the ultimate verification of the technique requires the operation of two instruments working in unison. There is only so much you can test with a single instrument.

In addition to that, a single instrument can do no astrophysics at all. It is simply not an operational instrument. So when you make a cost analysis of the construction of a single instrument or a double instrument, the double facility far, far outweighs—it is far, far preferable to the single one. In fact, it is the only way to establish and confirm this discipline.

Of course, as my colleague, Dr. Tyson, indicated, you can always do more and more R&D in a certain area. There is never an end to it. But somewhere you have to decide to take the next step because you feel it is now the time when you can make a gigantic step forward. We feel this is the situation now.

I should like to point out another factor. The endorsement for taking this next step, after all, was done after extensive peer review and analysis of the project. I should like to point out that all the officially appointed peer review committees which have reviewed LIGO have not only strongly endorsed the project, but they have also strongly endorsed going ahead with the present program. These were people who spent weeks and months and visited CalTech and worked with the team going deeply into this matter.

My distinguished colleague, Dr. Tyson, with whom I talked for the first time in my life last week, at the time when we talked with each other, he was certainly not familiar with LIGO. He has done a fantastic job as a brilliant scientist in getting himself up on the curve about LIGO. But there is only so much you can do in one week. I would like to recommend again that evaluation of LIGO be left, or I would strongly urge, that the recommendation of the peer review committees which have acted on LIGO be taken into consideration.

Mr. THORNTON. Certainly the recommendation of the peer review committee should be taken into consideration. There are, however, a number of materials problems that have been referred to, for example, the development of a new form of stainless steel, so that you can eliminate the hydrogen content of normal stainless steel in order to protect the vacuum to the level required, the need to detect displacements of a dimension of approximately one atom.

I was concerned as I listened to the testimony that the LIGO project, as presently conceived, would not be or might not be able to detect the gravitational waves from the binary star, the neutron star complex which has been useful at Princeton in formulating the existence of the gravitational waves. Is there greater sensitivity needed? Do we need a breakthrough?

Dr. VOGT. We do not need a breakthrough to achieve the sensitivity. In fact, the LIGO, the four-kilometer LIGO is designed in its initial operation to discover these binary neutron stars. We do not need breakthroughs in that. We can, as we go forward, improve the band width of this detector. We can go to lower and lower frequencies.

But my own calculations, which have again been confirmed by peer review, and the calculations of my colleagues, indicate no fundamental problems, no fundamental obstacles to reaching that.

You mentioned the stainless steel. This is something which should be mentioned that we at LIGO are extremely proud of. It is a good development between an industrial partner and the LIGO team. Incidentally, industry put in its own money to supplement the Government money, in order to produce this new capability. We have tested this steel. It is performing extremely well. We have made large-scale demonstrations of it.

In fact, the major cost of the LIGO, 90 percent of the cost of the LIGO, lies in the brick and mortar. It lies in the buildings and in this gigantic vacuum system. Every single aspect of this vacuum system has been proven in demonstration experiments, the manufacturing techniques for the steel, the assembly techniques. How the tubes get assembled. How they get degassed. All of these factors have now been demonstrated totally satisfactorily. It is probably one of the technologically best prepared projects which you have ever seen.

The one area where there will be continuous development will be with the detectors which we put into this vacuum system. As a member of CalTech, who is very well familiar with the development of optical astronomy at Palomar—in fact, I have been involved in the design and building of optical and radio observatories—Palomar started out with photographic plates. These were the original detectors for the big telescope, which had miserable efficiency. They had a few percent efficiency. Today they are using CCDs, charge coupled devices, which have almost 100 percent efficiency. The grand development over the last 50 years was for these instruments which go on the big facility.

In this same sense, LIGO will have continuous development of its interferometers to better and better performance.

Mr. THORNTON. Thank you, Dr. Vogt. I would like to ask Dr. Tyson first, and then Dr. Will, to respond to the question I addressed to Dr. Vogt.

Dr. TYSON. Thank you. I agree with Dr. Vogt that that project, the LIGO research project, if you will, at CalTech and MIT, has a track record of excellent research and a very healthy relationship with industry. They are making use of the latest technologies in a number of fields, vacuum technology, mirror optical technology.

Yet I must respectfully disagree with regard to the noise on these things. I have been doing gravitational wave astronomy since 1969. I have been keeping with this other way of measuring gravity waves, which by the way I think is the best way to go, this LIGO detector, for a number of years, since perhaps 1980 or so. I have talked to literally everybody associated, bar one person, with the project, in the last week or so, or who used to be associated with the project. I think I have a fairly good understanding of the noise level and the possible sensitivity to astronomical sources.

Mr. THORNTON. Do you have material you would like to have included in the record?

Dr. TYSON. Yes.

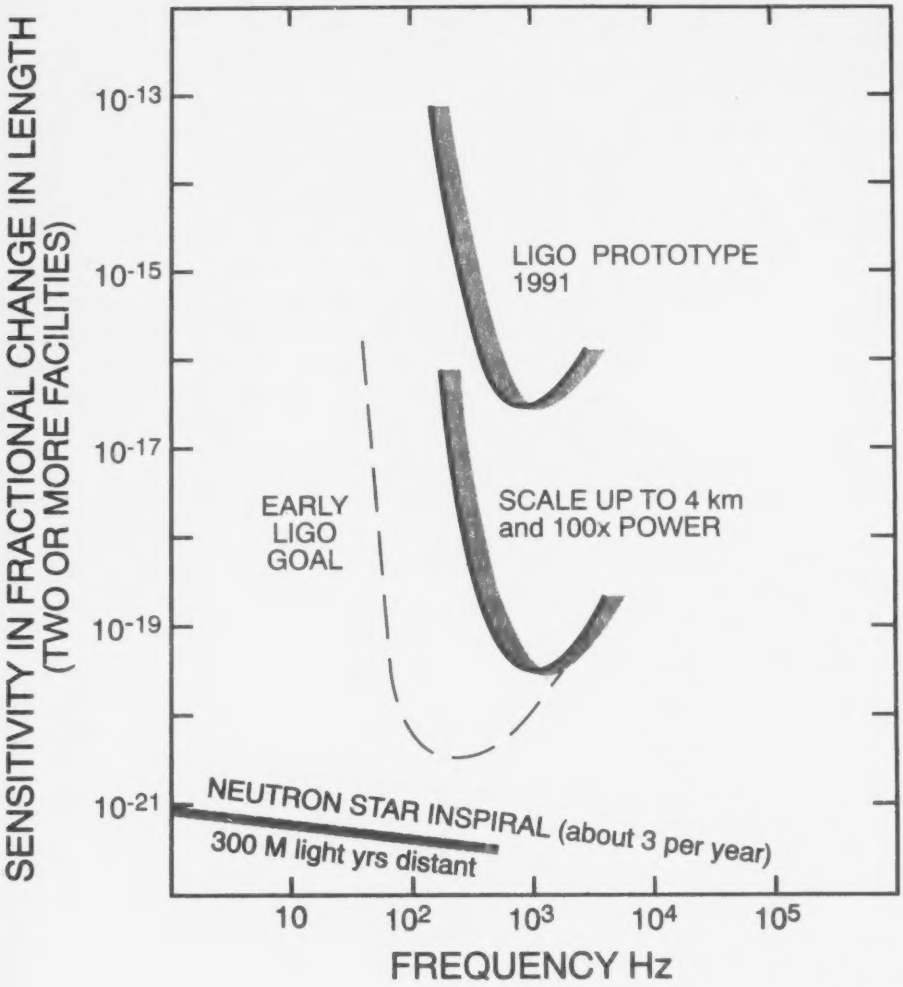
Mr. THORNTON. Without objection, the document will be included.

[Material to be supplied follows:]

Figure Caption

This figure shows my reading of the status of the LIGO project in early March 1991, for the detection of bursts of gravitational waves: the status of the LIGO prototype; what would be achieved by scaling up to 4km now; the stated goal for LIGO; and the strength of the only certain sources. Sensitivity (fractional change in length) is plotted on the vertical axis. Advances in sensitivity move you down the graph. The operating frequency (in Hz) is plotted horizontally. The detector sensitivity curves are for the case of a coincident detection by at least two LIGO detectors: 90% confidence of reliably detecting three real events per year. This would require at least two LIGO facilities widely separated. At least three facilities would be required to extract useful physics from an event, in general. The 1991 Caltech LIGO prototype (with its current internal noise) [upper shaded curve], when scaled up to 4km and 100x the effective power, results in the roughly 1000x improvement in sensitivity shown [shaded curve marked "scale up to 4km ..."]. On the other hand, elimination of the excess internal noise in the LIGO prototype would result in the sensitivity curve shown as a dashed line ["Early LIGO goal"]. Note that this would be within a factor of ten of reliable detection of the approximately three expected neutron star binary deaths per year out to a distance of 300 million light years. Occasional stronger events at a level above 10^{-20} might occur, but their rates are probably low (one per ten or thirty years). Most gravitational wave burst events are likely to fall off the bottom of this graph.

LIGO DECTECTOR SENSITIVITY



Dr. TYSON. What this is going to show you is my best reading of the situation with the signal-to-noise-ratio with the current detector, and where the LIGO hopes are, in terms of where they would like to go. This is a two-dimensional plot, vertically is sensitivity. Really sensitive things are in the bottom. Poorer sensitivity is on the top. The units are fractional changes in length, when a gravity wave goes by, a length changes. This is for two or more facilities, so that one actually has, as Dr. Vogt pointed out, a real observatory.

The only source we know that currently exists that we can depend on is the neutron star binary which is shown at the bottom. You have to go out to about 300 millon light years before you get enough of these things so that you can get a rate of about three per year.

Now, it is true that if by some chance one of the neutron star binaries in our own galaxy or one of the very nearby galaxies happens to spiral in on itself unannounced, the LIGO detector which is this dashed line here, could detect it. But the chances of that happening, most astrophysicist feel, are one in 50 years, perhaps, or one in 30 years.

In green on the top is my reading of where the current LIGO is, the prototype, 1991. In orange, or yellow, just down below it, is where that curve would go if you stepped up the length of the LIGO arms to four kilometers. That's the majority of the cost, and increased its power. Both of those are straightforward things.

But you can see that it is not going to get you where you would like to go yet. There is a lot of work that needs to be done in getting rid of this extra source of noise. I don't know what it is. When I first looked at it last week, the seismic noise effect, (I say so in my written testimony) that really ought to be revised to "unknown" source of noise.

Mr. THORNTON. Unknown.

Dr. TYSON. So I think there is quite a bit of development that needs to be done on the prototype, to understand this source of noise, to get rid of it, and then scale it up.

Mr. THORNTON. Thank you.

Dr. WILL. I would like to respond to one point you made. You mentioned that a breakthrough or some discovery needed to made and referred to this binary pulsar that was studied by Joe Taylor at Princeton.

Mr. THORNTON. Yes.

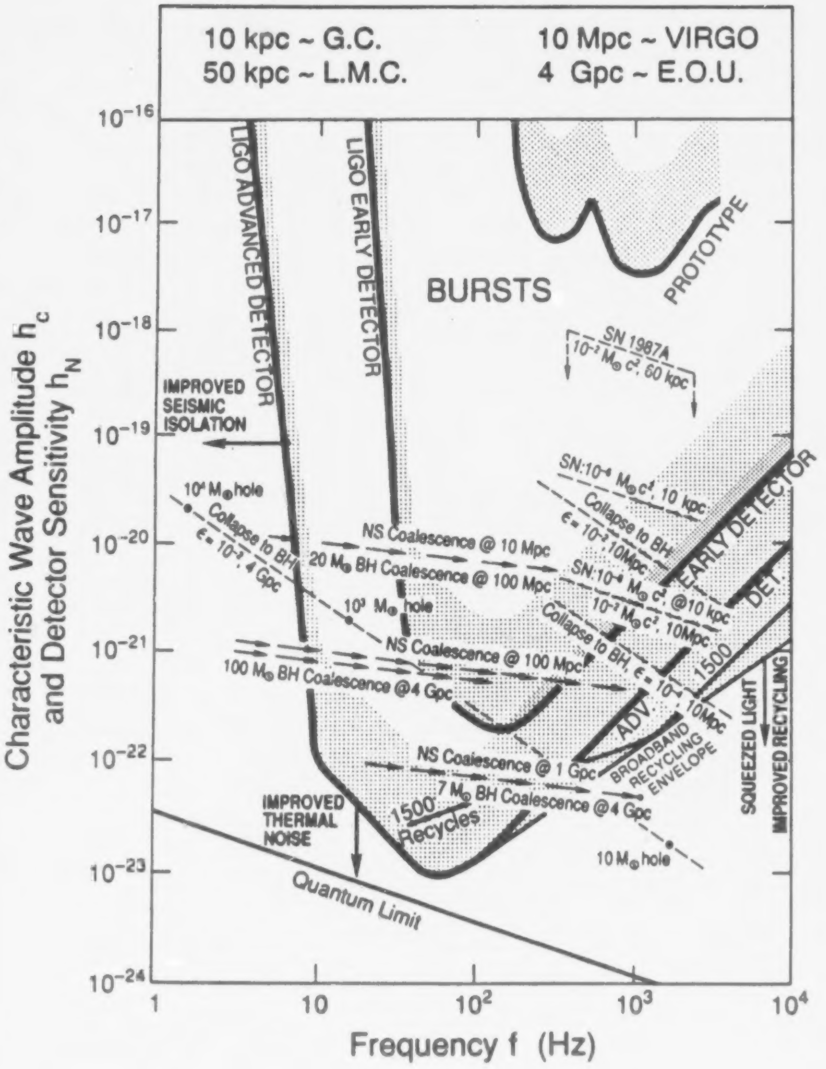
Dr. WILL. That particular system is irrelevant for LIGO. The gravity waves from that system are at too low a frequency for LIGO. That binary system is in some sense the prototype for these coalescing binaries that are the ultimate goal. In 100 million years, that particular Taylor binary system will lose gravity wave energy and spiral in and produce one of these coalescing systems. So the implication is today there are systems like that, doing that same final collapse. That's the kind of source that is shown here.

Mr. THORNTON. Thank you, Dr. Will. Dr. Vogt, do you have any comments?

Dr. VOGT. Yes, Mr. Chairman, if I may just respond to the graph which has been produced by Dr. Tyson. Unfortunately, as I said, apart from contacting me and asking me for input of material, Dr. Tyson has never discussed his conclusions on anything with me, so this comes as a total surprise to me. I am seeing it for the first time.

I must state that upon a brief inspection of the graph he shows us, I think this graph is in error. I have here in front of me a similar graph produced by the LIGO team which is part of our LIGO proposal which has been peer reviewed, which has been certified, which obviously disagrees with the material presented by Dr. Tyson.

[The graph referred to above follows:]


10 kpc ~ G.C.
50 kpc ~ L.M.C.
10 Mpc ~ VIRGO
4 Gpc ~ E.O.U.
Characteristic Wave Amplitude h_c
and Detector Sensitivity h_N
Frequency f (Hz)
10^{-16}
10^{-17}
10^{-18}
10^{-19}
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
1
10
10^2
10^3
10^4
LIGO ADVANCED DETECTOR
LIGO EARLY DETECTOR
BURSTS
PROTOTYPE
SN 1987A
$10^{-7} M_\odot c^2$; 60 kpc
IMPROVED SEISMIC ISOLATION
$10^4 M_\odot$ hole
Collapse to BH
$\epsilon = 10^{-7}$; 4 Gpc
NS Coalescence @ 10 Mpc
20 $M_\odot$ BH Coalescence @ 100 Mpc
10^3 $M_\odot$ hole
SN:10^{-4} $M_\odot c^2$; 10 kpc
Collapse to BH
$\epsilon = 10^{-2}$; 10Mpc
SN:10^{-4} $M_\odot c^2$; @10 kpc
$10^{-7} M_\odot c^2$; 10Mpc
Collapse to BH, $\epsilon = 10^{-7}$; 10Mpc
EARLY DETECTOR
DET.
1500
ADV.
NS Coalescence @ 100 Mpc
100 $M_\odot$ BH Coalescence @4 Gpc
NS Coalescence @ 1 Gpc
7 $M_\odot$ BH Coalescence @4 Gpc
BROADBAND RECYCLING ENVELOPE
SQUEEZED LIGHT
IMPROVED RECYCLING
IMPROVED THERMAL NOISE
1500 Recycles
10 $M_\odot$ hole
Quantum Limit

Dr. **Vogt**. So the early LIGO detector—first of all his assertion that neutron star would spiral for 300 million light years is the one—this is incorrect. We can get that from a cluster at ten times closer distance.

What you have here is simply a disagreement between a scientists who has worked one week on this problem and a team of scientist which has worked for ten years on the problem, which has been extensively peer reviewed, and whose work has been certified by peer review. I do not think it is possible to resolve that scientific disagreement here today, in this hearing.

Mr. **Thornton**. Nor indeed will we try to resolve it here today. Is that graph which you have, is that included in your materials?

Dr. **Vogt**. It is not included, but I will include it.

Mr. **Thornton**. We would be pleased to receive that graph as part of the record.

I would like to recognize Mr. Packard for his questions.

Mr. **Packard**. Thank you.

What is the scientific significance of proving the black hole, the existence of a black hole?

Dr. **Vogt**. There are several aspects to it. There is a physics aspect and an astrophysical aspect to it. The physics aspect is that a black hole is probably one of the most difficult physics phenomena which is presently being theoretically studied.

A black hole is not simply a place of intensive gravity where light cannot escape. A black hole actually, as my colleague Dr. Will indicated, when it is being formed, or when it collides with another black hole, rings like a bell. It has oscillations. It is a state of nature, and a state of matter which is so highly non-linear and so unusual that if studied will tell us an awful lot about our understanding of physics.

At the same time, a black hole is an astronomical object which is the driver of many of the most mysterious objects we are seeing in the sky, like quasars, or things like that. It is the energy source for that, and we want to study this particular energy source with very great attention. There is a totally new physics in there which we need to understand.

Black holes are one of the Holy Grails of astronomy, which all of us are very fascinated with.

Mr. **Packard**. What breakthroughs or progress would need to be made to make LIGO obsolete or unnecessary, anyone?

Dr. **Vogt**. It is generally recognized that both for theoretical and practical reasons, it is presently the best known, has the highest potential for sensitivity in gravitational wave detection. It is laser interferometry. We know at the present time of no other technique which could be more sensitive. It is very easy to explain.

For example, the resonant bar technique, which Dr. Tyson has worked on in the past, studies the behavior of a large block, a cylinder of aluminum. This rings like a bell when a gravitational wave hits it. But the mechanism which limits its performance, among other things, is the velocity of sound, which takes place in this object.

In the laser interferometer, it is the velocity of light which limits its sensitivity. There is nothing in nature which has a higher velocity than light, consequently laser interferometry probably is the limit of the technology which can be used in order to get the highest sensitivity.

Mr. PACKARD. The work that is being done at Princeton, does that have the ability to make LIGO unnecessary?

Dr. VOGT. No. In fact, the work in Princeton, which is done by Professor Taylor, is an indirect deduction of the existence of gravitational waves. Princeton has not made a direct detection of gravitational waves. In fact, Professor Taylor, who is the man who performed this marvelous work, was one of the peer reviewers who has endorsed LIGO very strongly.

But the work in Princeton is taking place at a much lower frequency. It is radio astronomy, and it deduces the existence of gravitational waves by indirect means. But it does not actually measure gravitational waves. You see, the beauty of measuring gravitational waves is to decipher the message which is imprinted upon the gravitational wave. In the same way as I told in my earlier testimony, as a symphony concert is imprinted on a radio wave which comes to us, the gravitational wave in a broad-band detector like LIGO, will have a tremendous amount of information which can be deduced by studying the wave shapes. This is absolutely inaccessible to the method of indirect observation.

Mr. PACKARD. Is it possible to go much further with LIGO without a physical facility, without a building?

Dr. VOGT. Clearly we would not be going through the agony of proposing the upscaling of LIGO at this stage if we did not feel the time is right and the best way to progress to the next step is to scale it up. Many of the refinements we are talking about cannot be tested on the prototype. They can only be tested on the full-scale model, and we are prepared to do that. It is simply our judgment that this step should be taken, and again this judgment has been reinforced and confirmed by all reviews which have been taken.

Mr. PACKARD. How dependent is LIGO upon the Hubble Telescope, or is there any connection?

Dr. VOGT. None at all.

Mr. PACKARD. None at all.

Dr. VOGT. There is obviously a connection in that we are looking at related or similar objects, and we obviously would like the Hubble Telescope to be as successful and as strong as it can be.

But we, in the same sense, think—for example, we look at the universe through LIGO through a different force, not only a different wave length. It is the same when you look at a human being in visible light, you see the exterior, and when you look at a human being through x-rays, you see the bone structure and everything. But there, in electromagnetic astronomy of the human body, there is only a change in wave length.

Here, LIGO proposes to use a new force, a totally new domain. And that of course has great fascination. But at the same time, we are pioneers. It is not so that we have an established constituency which is already familiar with the technology and its objectives. There are very few practitioners who are presently familiar with the materials.

Mr. PACKARD. Thank you, and thank you, Mr. Chairman.

Mr. BOUCHER. The Chair thanks the gentleman. I have a series of questions which I would like to propound to each of the panelists.

First, let me report some information which the subcommittee has, which I don't think has been discussed during the course of the statements of these witnesses so far.

The National Academy of Sciences, every ten years, assembles a panel of astronomers. They ask that panel of astronomers to list the new research facilities that will be necessary in the general field of astronomy, then to rank those facilities in the order of priority. The report of that panel of astronomers is due to be released in the course of the coming month. In fact I think at the end of this month. It does rank in order the new research facilities that are necessary in astronomy, in the opinion of this panel assembled by the National Academy of Sciences.

It is the subcommittee's information that the panel did consider the LIGO project during the course of assembling its upcoming report, and decided not to include the LIGO project on its list of priorities. So that project, for the present, is not being recommended by the astronomers assembled by the National Academy of Sciences.

Now, with that factual base, the question I have for each of you is, given that review by these astronomers, given their conclusion that the timing is not right for the construction of this project, do you believe that we should go forward with this funding, totalling some $211 million over the course of the next five years, or should we take a more modest approach and perhaps approach this project incrementally, do some additional work in the test bed, before launching into full construction?

Dr. Tyson, let's begin with you.

Dr. **Tyson**. Thank you. My opinion is that there are sources of noise that could be studied with the prototype. It is a complex servo system, and those should be understood before scaling up. If you take a look at the figure that Dr. Vogt kindly supplied you with a few minutes ago, at the very top there is a stippled area. If you take a look at the top of that, that is the 90 percent confidence factor sensitivity of the prototype, and there is a dip on the right hand side which is in fact the CalTech prototype that we are talking about.

The dip on the left hand side there, it goes down again slightly, is a European version of LIGO that operates on a different principle. I think this LIGO detector is our best shot, I agree with Dr. Vogt, for gravitational wave astronomy in the future. I don't think the kinds of detectors the rest of us have been working on for so long are going to pan out in terms of being a very good detector for gravitational radiation. I think it is premature, however, to scale up to that size before studying some of the limiting problems with the current detector.

On the question you just asked, regarding the National Academy study, I gather that the LIGO did not make the final cut. I was not on the subpanel that discussed LIGO, although I hear from my colleagues that it was discussed. Astronomy has benefitted over the years from inheriting technologies and ideas from physicists.

I think over the last 30 years, you can see that the astronomical sciences have become a much more healthy field as a result of the collaboration and collusion between physicists and astronomers. X-ray astronomy, gamma ray astronomy, radio astronomy—new windows on the universe were opened up largely by the work of physicists, over, very often, the skepticism of astronomers.

So I think it would be a cheap shot, and an incorrect reading, to take the view of the entire astronomical community and take a poll of the astronomers and they come out against some kind of new technology the physicists are claiming is going to be great, to take that as being the be all and end all.

On the other hand, that subpanel was composed of people who had thought about this issue deeply.

Mr. BOUCHER. Dr. Will, do you have a comment?

Dr. WILL. Yes. I would like to reiterate the point that it is not clear that the astronomy panel has left LIGO off for intrinsic reasons, rather they may have left it off in the sense that it is really a physics project and have not really appreciated the astronomical implications of LIGO. So it is true that LIGO has an important physics component in terms of studying this fundamental dynamic force, being able to understand the physics of black holes and neutron stars, but I would still argue that in the long run, there is a strong astronomy that can be done with gravitational astronomy, and LIGO in particular.

Mr. BOUCHER. Dr. Vogt?

Dr. VOGT. Mr. Chairman, first I would to make a factual correction. Dr. Tyson was referring to the graph which I just presented for inclusion here, and he referred to one dip being the CalTech prototype and the other being the European detector. Again, he is confused. What is shown here on this graph is the totality of the CalTech spectrum. There is no European component on it, and I should know, because it is my own instrument which is being represented here.

This just indicates the degree of confusion.

However, about the astronomy survey, Mr. Chairman, far be it from me to try to correct your impression. However, I do have personally also some advance knowledge, which was communicated to me by the National Science Foundation. The National Science Foundation specifically agreed with the astronomy survey committee that LIGO should not be ranked because it was not relevant to that survey. That is the reason why LIGO is not being ranked. LIGO was not ranked lowest. It was decided that it was inappropriate to rank it with these other astronomy instruments.

In addition to that, since LIGO was already last year before Congress for possible approval, the same thing is done with astronomical instruments which are already underway, so to say, or before Congress. They no longer get ranked. This is clearly my impression, that it did not fail to make the cut, but rather it was decided not to be included with the full understanding between the astronomy survey committee and the National Science Foundation.

Mr. BOUCHER. Thank you for that very precise answer. We will know more, obviously, about the rationale for the recommendations of this panel once that report is made public. We have only had at the subcommittee staff level a preliminary briefing as to the findings. Obviously, those and other questions will be answered in more detail when the report is released at the end of this month.

Let me move to another subject of inquiry. I gather that there is some lack of unanimity of opinion with regard to the exact steps that ought to be taken with regard to LIGO now. I think all of these witnesses this morning have indicated that it is a valuable project. There is simply some disagreement as to the exact steps that ought to be taken in the near term.

Dr. Tyson, would you like to give us your advice as to precisely what steps ought to be taken in the near term to move the LIGO project forward in logical sequence? What should we be doing now, and give us some time frame, if you can, between that first step and the time at which we ought to be building an initial detector facility?

Dr. TYSON. It is difficult for me to give you a time frame for research. My boss often asks me to do the same thing. I would definitely explore the possibility of getting rid of some of these interfering sources of noise on the prototype, first through—I don't want to get too technical — but there are some very high quality super-mirrors that are available in the high technology optical community now which could be incorporated with extremely high reflectivity. That would perhaps help in the diagnosis of this other source of noise.

A larger facility, slightly larger facility, larger vacuum tubes, etc., would be required for this, although I think there are plans afoot already, if I am not mistaken, at CalTech, to go ahead with this anyway in the next few years.

How long the shakedown might take—I don't know. It's anybody's guess. I would hope that it would take no more than a few years. If at that point this kind of incredible sensitivity is obtained in the prototype, then one could confidently predict that one could get the required sensitivity that is shown by the upper so-called early detector curve by this scale-up, this enormous investment of effort.

Mr. BOUCHER. Okay. Does anyone else care to comment on that question?

Dr. Vogt?

Dr. VOGT. I obviously would like to. Incidentally, Dr. Tyson refers to the super-mirrors which might help. I would like to say again, in collaboration with industry, we have developed the very best super-mirrors and the green light which we are using. Nobody has anything comparable to the ones which we have in hand. We do not know how to get better ones because we are the ones who have developed them. We have the very best in these wave-lengths.

The question of what would be the best progress here, Mr. Chairman, I should like to remind you that what we are building here now, what we are committing to, is a large vacuum system in which detectors are being inserted. These detectors are what Dr. Tyson and I have disagreements on, what exactly their performance is.

We have five more years, while we are building the facility, to further refine and develop these detectors. We have very concrete plans. We have in hand today the means to remove many of the noise sources which Dr. Tyson is talking about. However, we do not presently have the means—we will have to spread out our work simply because we are not funded that heavily that we can do everything at one time. We cannot arbitrarily increase our staff.

But we believe we have five years to refine these techniques, what we are putting into the system. And what we are putting into the system is rather inexpensive. The big vacuum system in the buildings cost more than 90 percent of the money. A complete laser interferometer detector, which goes into the system, is a few million dollars. On these detectors, there are some uncertainties.

However, Dr. Tyson has not given me a chance to explain to him what we have up our sleeves. What we already have in the works. What we have not implemented yet for lack of time. But we do know what we are doing in this regard, and for that reason we believe we are ready now to take the next step.

Mr. BOUCHER. Assuming for the sake of argument that you are, why shouldn't that next step be taken in partnership with some of the other countries that are also interested in establishing LIGO-like facilities? I understand there are basically three sets of countries that have that on the agenda. One set is Japan and Australia, another Britain and Germany, another France and Italy. Why should the U.S. essentially be building these expensive facilities on its own? Why not do it in partnership with one or more of these international sets?

Dr. VOGT. There are two aspects to the answer here. First of all, I should like to emphasize that I have spent immense efforts exploring that possibility with the foreign teams. There are reasons why the foreign teams have basically decided they would like to retain their autonomy. We are cooperating very closely. There is a significant amount of technology transfer going on in both directions.

So there is a collaboration. What the foreign teams are doing is building the third and fourth facilities for this international network.

There is a second reason. The United States presently has a very significant lead in this effort. We are much further ahead in the design of such facilities, and in the art which is required to implement it. We are the leaders. In fact, the foreign governments looking at us here in the United States, every time LIGO hiccups, the foreign efforts go into a tailspin. Some of the present funding difficulties which the foreign efforts have, are the result of the perception that LIGO might be in trouble in the United States.

If LIGO does not go forward, the foreign efforts, in my opinion, will be stopped.

Mr. BOUCHER. Dr. Will?

Dr. WILL. One other issue is that in order to do any astronomy whatsoever, you need at least three LIGO systems, widely separated. One detector can't confirm that you have gravitational waves; two can do it, but can't determine the direction to the source. But with three detectors, you can determine where the source is, with one ambiguity. With four you can absolutely determine where the source is, and then you can coordinate those observations with optical and other observations, and do some real astronomy.

So to say that one should build one detector in the United States and one in Europe really doesn't make much scientific advancement for the money that is invested. You really need two and one or two and two, a minimum of three.

Mr. BOUCHER. Dr. Tyson?

Dr. TYSON. I agree with that. I agree with Dr. Vogt's and Dr. Will's comments on that.

Mr. BOUCHER. So the three of you are in agreement that if we decide to build LIGO at all, we should build two detectors in the United States? Are you in complete agreement on that? Dr. Tyson?

Dr. TYSON. If you decide to build, if you decide to scale up now. Scientifically, if you can make the argument that yes, the prototypes are working correctly, by scaling up you are going to have—if everyone scales up and you have two in Europe and two in the United States, you will have an observatory, yes, at that time.[1]

Mr. BOUCHER. The Chair thanks this panel and would recognize the gentleman from Maryland, Mr. Gilchrest.

Mr. GILCHREST. Thank you, Mr. Chairman. I suppose I am going to ask some pretty fundamental questions, but I don't know the answers, so I am going to ask them.

The first one is kind of a fascinating question for me, and I hope everybody else. Black holes—is there a black hole at the center of our galaxy? Are there black holes at the center of all galaxies, and is that why galaxies stay together in a rotational manner?

Dr. TYSON. The answer to the last part of your question is no. The black holes that are hypothesized to exist at the centers of some galaxies probably are not more massive than 100 million solar masses. Whereas, a galaxy itself is at least 10 billion solar masses. So it does not dominate the dynamics of the galaxy. But it will dominate the astrophysics of what happens near the core of the galaxy.

If you have a black hole near the center of a galaxy, it is a very bad neighborhood to live in. There is a lot of matter falling into this thing, and it creates a lot of radiation. And you can see it, not necessarily with gravitational wave detectors, but black holes are thought to be seen at the centers of certain galaxies now, because the signature in the optical and x-ray suggests that they are there.

Mr. GILCHREST. Do we have one at the center of ours?

Dr. TYSON. That is being debated.

Mr. GILCHREST. But we would not have to worry about, I guess, for a little while?

Dr. TYSON. Not in the fiscal year 1992 time scale.

[Laughter.]

Mr. GILCHREST. Very good. Could you give me a simple explanation? When you get near one of these black holes, you made reference to—and anybody can answer this one—warped space-time. Do we have a sense of what that is and can we commercialize that in any way?

Dr. WILL. No, not yet. When you are near a black hole, locally, in a very small spaceship that is freely falling near the black hole, if it is a supermassive black hole, such as near our galaxy, you will feel essentially nothing. There will be some tidal forces similar to the tides that distort the shape of the earth and oceans. You will feel those, but they will be rather modest. You can fall into the black hole without feeling anything strange whatsoever. By that time, of course, it is too late, and you are consigned forever to the interior of the black hole and will never get out.

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[1] See Appendix IV for additional information submitted by witness.

So in the local region near the event horizon, the surface of the black hole, nothing particularly unusual happens. So it is really in a global or astronomical sense that the black hole is important, because anything inside never gets out. So people outside will never receive any future communications from anyone who falls in.

Dr. VOGT. If I could just add something to that, Dr. Tyson already correctly indicated, you infer from optical astronomy that there might be a black hole. The only way to study the behavior and dynamics of a black hole or its internal actions and vibrations are through gravitational waves. There is no other way.

In fact, there was a New York Times article only last Friday which indicates a very interesting result of a calculation done by two theoretical astrophysicists who have simulated the interaction, the behavior of a black hole, the formation of a black hole, with a supercomputer for the first time. What they discovered is that there are two kinds of events which can happen. They can either have an event horizon, which Dr. Will just described, where you cannot look inside. But they also had the surprising result that there might be a so-called naked singularity which would be totally exposed.

But in any case, the actions and behavior of the black hole in its inside, its mechanics, will be revealed through the emission of gravitational waves, which basically are being transmitted through the event horizon, which has been mentioned. So gravitational waves will be able to study what is going on in a black hole.

Mr. GILCHREST. Would we then—maybe you already know this—understand exactly what gravity is and why it always works? Why do we have gravity? I know it has something to do with the mass of an object, maybe the speed of an object. The central force in the universe—do we understood what gravity is, and if and when we find out what it is and how it works, how will we benefit from that?

Dr. WILL. In a very strong sense, we already understand a great deal about gravity, because of the experimental verifications of Einstein's theory that have been done over the past 30 years. They tell us that gravity is really a manifestation of curved space-time. When we throw a rock up, it falls to the earth because it is moving on a path in this warped space-time that surrounds the earth. The light ray passing the sun is bent because of the curved space-time near the sun. That's all that gravity is, according to Einstein's theory. We now believe it with extraordinary precision.

A black hole is simply the extreme of that, because it is so dense, and matter has been compacted. The curvature of space-time is so strong that once you get inside, you simply cannot escape to the exterior. Space-time is so strongly curved.

Mr. GILCHREST. I could go on, Mr. Chairman, but I guess I had better stop.

Mr. BOUCHER. The Chair thanks the gentleman and recognizes the gentleman from Illinois.

Mr. BRUCE. I have enjoyed listening to the testimony. I have no questions.

Mr. **Boucher**. Well, gentleman, thank you very much for assisting us this morning with a very complex and interesting subject. We will be having further deliberations on it.

We welcome now our third panel of the morning to talk about the new materials initiative at the National Science Foundation. I would like to yield at this time to the gentleman from Illinois, Mr. Bruce, who will introduce one of the panelists.

Mr. **Bruce**. I appreciate that, Mr. Chairman. I would like to introduce Mr. James Economy, from the University of Illinois. He is a Professor of Materials Science and Engineering at the University of Illinois and is on the National Science Foundation Materials Science Advisory Committee. We look forward to his testimony today, enlightening this committee. I appreciate the courtesy extended by the Chairman.

Mr. **Boucher**. The Chair thanks the gentleman.

We also welcome Dr. Philip Anderson, Professor of Physics at Princeton University, and Dr. Praveen Chaudhari, IBM Watson Research Center, and Co-Chairman of the Committee on Materials Science and Engineering for the National Academy of Sciences.

Without objection, your statements will be a part of the record. We would be pleased to receive an oral summary of your testimony. Dr. Economy, we will begin with you, sir.

STATEMENT OF DR. JAMES ECONOMY, PROFESSOR OF MATERIALS SCIENCE AND ENGINEERING, UNIVERSITY OF ILLINOIS

Dr. **Economy**. Thank you, Mr. Chairman, and thank you, Mr. Bruce for that introduction. Let me also add to the experience that I have had in the educational field that I spent approximately 33 years in the management of materials R&D in industry. So I bring a little bit of experience from that side to my very brief experience at the University.

Let me start by stating that I very strongly support the new NSF initiative on materials synthesis and processing. To my knowledge, it represents the first serious attempt to address the deterioration of our Nation's infrastructure in materials R&D as spelled out in the recent NRC report on Materials, Science and Engineering for the 1990s.

I also strongly endorse that the $25 million increment for fiscal year 1992 be used solely for the support of individual investigators as well as small teams since it provides a major step towards correcting the recent problems in this area. The specific themes selected by the NSF directorates for special emphasis in fiscal year 1992 includes synthesis and processing of electronic and photonic materials, bimolecular materials, and biomaterials. These represent areas which have been seriously underfunded in the past, and from an industrial view, are currently witnessing a very rapid growth rate.

With respect to instrumentation, the $25 million increment is only intended for support of individual investigators, although a modest amount of money could be used at the discretion of the principal investigator for building required instrumentation.

Let me comment on another aspect of this initiative, namely the goal to strengthen the competitive position of U.S. industry in developing and using next generation materials, synthesis and processing. This is a very important aspect of the NSF initiative, since today large sectors of our materials industries are in a state of disarray and are desperately in need of this kind of support.

For example, practically all the major ceramic and refractory companies in the U.S. have over the past two decades sharply reduced their research activities, while the two largest refractory and abrasive companies have come under foreign ownership. Most of the metal industries have either greatly reduced or eliminated their R&D, and that which remains tends to focus on very near term goals.

The chemical industry which in the past pioneered the plastics revolution, has greatly de-emphasized work on the development of new polymers and now looks to diversity into higher value-added markets, and thus compete with some of its former customers.

On the other hand, those industries such as electronics, motors, aircraft, and so on, who have critical needs in new and improved materials for the most part still look to the traditional materials suppliers to fill their requirements.

I think you can see then why I feel so strongly about the NSF initiative under consideration here. It represents a very important first step in establishing the kind of infrastructure in materials synthesis and processing essential for the advanced technologies of the future. Not only can this program lead to a new kind of researcher trained in a broad spectrum of materials synthesis and processing, but also greatly increases the potential for discovery of revolutionary materials with new and unexpected properties.

Thank you.

[The prepared statement of Dr. Economy follows:]

Written Statement
Proposed NSF Initiative on Materials Synthesis and Processing

by
J. Economy
The University of Illinois at Urbana-Champaign

Introduction

It is a pleasure to testify before the House Subcommittee on Science concerning the proposed NSF initiative on "Materials Synthesis and Processing". I will first address the specifics concerning the NSF initiative and then summarize my views on why this initiative is so critical with respect to the international competitiveness of many of our industries. This latter part will include 1) a brief historical review of industrial R&D on materials 2) a comparison of what is happening in other countries vs the USA on materials synthesis and processing and 3) a vision of the future. These latter views are drawn primarily from my 33 years in managing industrial R&D.

Assessment of NSF Initiative on Materials Synthesis and Processing

With respect to the new NSF initiative in materials synthesis and processing, I believe this represents the first serious attempt to reverse the continuing deterioration of the national infrastructure in advanced materials. These needs and concerns were summarized effectively in the recommendations of the NRC Report on MSE for the 1990's. The proposed $25 million increment is properly focussed on individual investigators and or small groups and is expected to support 215 principal investigators, 300 graduate students and 70 post docs. These grants will, on the average be 30% larger in dollar amount than current awards from the NSF, thus permitting greater flexibility in purchase or construction of required instrumentation.

Concerning the question of the appropriate balance between support of individual scientists and interdisciplinary groups, there is strong evidence that support for individual investigators has decreased significantly over the past decade. Hence, the use of the $25 million increment for individual investigators is most appropriate. This issue should be reassessed in the succeeding years of the initiative to insure that an appropriate balance is maintained with larger interdisciplinary programs.

In the proposed 1992 NSF budget request the $25 million increment is intended to focus on electronic and photonic materials, biomolecular materials and biomaterials, as well as new approaches to materials synthesis and processing. It appears very fitting that these particular themes receive initial emphasis since they are directed for the most part at those sectors of industry which are witnessing very rapid growth. Equally as important these represent areas that have not received significant attention in the past few years.

Historical Perspective on Materials Synthesis and Processing

From a historical view it is noteworthy that during the 1950's and much of the 1960's, US chemical, metals and ceramics industries were the world leaders in synthesis and processing of materials. In fact, the USA was at the leading edge in both research and commercialization of materials. An excellent example is the plastics industry where the USA led the way in commercialization of many of the major commodity plastics. It is noteworthy that a majority of the research staffs of companies such as DuPont were engaged in synthetic efforts on new types of monomers and polymers. Typically these scientists had to be trained by industry since very few faculty were involved in synthesis of polymers. However, starting in the mid to late 1960's the industries concerned with development of new materials sharply reduced their efforts to the point where very few if any have retained a capability to commercialize completely new materials. In effect, they have focused on incremental improvements in existing products and manufacturing processes.

Materials Activities in Other Countries

In Japan, starting in 1980 MITI defined seven areas for design of new and improved materials and large, joint industrial programs were established to carry out leading edge research in these areas over a 10 year period. With the recent completion of the first 10 year cycle, most of these programs have been renewed for another 10 years and a number of others initiated. In Europe, starting in the mid 1980's a number of activities can be identified; e.g. the German government has begun to foster closer interactions between the large chemical giants and the Max Planck Institute. It is noteworthy that the Max Planck Institute in Mainz is now the major center in the world for polymer research.and two of their major thrusts are in synthesis and processing. In France close collaborations have been established between CNRS (their Government Labs) and a number of materials related industries. As a backdrop a number of foreign companies have been acquiring key material industries in the USA such as composites fabricators or advanced metal alloy manufacturers with the intent of better participating in these obvious growth areas.

Current Status of US Materials Industries

Turning to the USA one can only describe the current state of affairs in our various materials industries as chaotic. The major ceramic and refractory companies have sharply reduced their research activities and several are now under foreign ownership. Most metal industries have either cut back or eliminated their R&D and that which remains tends to focus on very near term goals. The chemical industry which in the past pioneered the plastics revolution, has now de-emphasized work on new polymers and is attempting to diversify into some of the high value added markets where their traditional skills in materials could provide leverage. Those industries such as electronics, aircraft, automotive, etc., who have critical needs for new or improved materials for the most part still look to the traditional materials suppliers to fulfill their needs.

A Vision of the Future

It should be noted that the materials opportunities of the 1990's are indeed challenging from both a scientific and technological view. The level of sophistication required to address the problems of today is much higher compared to that required to deal with discoveries of several decades ago. On the other hand, for the very first time the potential exists to train students across a broad spectrum of materials including ceramics, metals, polymers, electronic materials, composites, and biomaterials. I strongly believe that the next generation of scientists trained in synthesis and processing in these six classes of materials will be in a position to make significant breakthroughs in design of new materials and processes that were not possible for scientists educated in an earlier era. There is little doubt that the international competitiveness of most of our high technology industries will depend very much on implementing the recommendations of the NRC Report. However, it is equally as important that such a commitment be fostered among our industrial and financial leaders.

Brief Biography
of
James Economy

Dr. Economy received his BS from Wayne State University (1950), PhD from the University of Maryland (1954) and was a research associate at the University of Illinois (1954-56). He worked at Allied Chemical as a general research leader on polyolefin research from 1956-60. From 1960-75 he was Manager of Chemistry and then of the Research Branch in the R & D Division of the Carborundum Co. During this period, he was responsible for the development of a number of advanced polymers and ceramics, eight of which are commercially available today. From 1975-89, he was Manager of the Polymer Science and Technology Department in the Research Division of IBM. His group achieved world-wide prominence both scientifically and technologically transferring two new materials/year (since 1981) to the operating divisions for use in advanced microelectronic hardware. In February 1989, he joined the faculty of the University of Illinois as Professor and Head of the Materials Science and Engineering Department.

He has carried out research on high temperature polymers, flame resistant materials, high performance composites, advanced materials for microelectronic devices and design of new materials systems for control of environmental contaminants. In recognition of his scientific contributions, he has received a number of distinguished awards including the AIC Chemical Pioneer Award (1987), ACS Phillips Medal (1985), the Southern Research Burn Institute Award (1976), Schoelkopf Medal (1972), and 14 IR 100 Awards for Outstanding Technical Developments in American Industry. He has published over 150 technical papers and received more than 70 US patents. He has served on numerous government committees and was chairman of the Polymer Division of the American Chemical Society (1985). He is a member of the National Academy of Engineering, the National Materials Advisory Board (1984-) the Materials Research Advisory Committee for the NSF (1989-) and is Vice President of IUPAC's Macromolecular Division (1990-94).

Mr. BOUCHER. Thank you, sir.

Dr. Chaudhari?

STATEMENT OF DR. PRAVEEN CHAUDHARI, IBM WATSON RESEARCH CENTER, YORKTOWN HEIGHTS, NEW YORK, CO-CHAIRMAN, COMMITTEE ON MATERIALS SCIENCE AND ENGINEERING, NATIONAL ACADEMY OF SCIENCES

Dr. CHAUDHARI. Thank you, Mr. Chairman. I am Praveen Chaudhari from IBM. For the last 25 years at IBM Research I have held various management positions, including that of vice president for science. But I am not here today as a manager at IBM, I am here representing the National Academy of Sciences and the National Academy's Engineering Report on Materials Science and Engineering that was completed in 1989.

I am pleased to give you my views of the National Science Foundation initiative on materials synthesis and processing in the context of that report. That report, which was triggered by Don Fuqua in a letter he wrote to Frank Press, the President of the National Academy of Sciences, requesting a study on materials research. Your committee's interest in materials encouraged a number of us to participate in that study. That study took some three years and involved 500 scientists before it was completed.

We recognized at the outset of that study that materials science and engineering is unique in the sense that it goes all the way from science, generation of knowledge, to the application of that knowledge. What we did as part of that study was to invite senior technical management people from eight major industries to join us in the study. Their views, along with those of researchers from national labs, universities and from industry, were combined to lay out the findings and the subsequent recommendations.

What I would like to do is list six major findings, and then put the NSF program in that perspective. Advances in materials sciences and engineering are essential and occurring worldwide. The United States is one of the lead players. It is not the lead player. Advances in materials sciences are essential to all manufacturing industries in a competitive environment.

In order for the advances to be utilized in a timely manner, a strong coupling between those that generate knowledge and those that apply it is required. In the United States, we must learn to do this more efficiently. We do not do it as effectively as some of our competitors do.

Within the broad field of materials science and engineering, the United States is particularly weak in the area of synthesis and processing. This is roughly the area which is concerned with making things. These could be things we use for scientific experiments, like making a crystal on which we make measurements, or it can be used for developing a process, such as inexpensive composites which might be used in our automobiles; or generating a knowledge base which leads to advanced semiconductor chips and packages.

The responsibility for correcting the state of affairs in synthesis and processing lies with the community, and it is our intent as members of that community, to inculcate in present and future materials scientists a feeling of cultural value of synthesis and processing.

We need to do a number of things. But two that are particularly important are the following. First, we need to share with our colleagues at universities the intellectual challenges in synthesis and processing so they can communicate this in turn to their students. Second, we need to increase the research base in this area, for it, more than any other aspect of materials science and engineering, abounds not only in intellectual challenge, but also in its impact on industry.

We are at an age where we can design and build new materials atom by atom, layer by layer, or vastly improve processes of traditional materials by using dynamic computer control and sensing.

The National Science Foundation is in a unique position to implement these changes. Its charter calls for developing human resources and scientific engineering knowledge. It is therefore appropriate and highly commendable that they be the first agency to respond to the challenges laid down by the Materials Sciences and Engineering Report.

Their foundation-wide response is particularly noteworthy. Collectively, they have laid out a road map for progress for five years. They have contributed a base of $59 million and they are asking for an increment of $25 million for this year. Both of these decisions, I believe, are prudent and I support them completely.

The specific areas of electronics, photonics and biomaterials have been identified for attention by the National Science Foundation. Electronics represents the most mature of these three industries. But it helps that industry which is characterized by relentless competition and progress. If all other factors are equal, progress in this field over the next 10 years will be determined by advances in this area of materials research.

Photonics, particularly optoelectronics, will be ubiquitous in the future. Combined with computers, it will change our lives at home and at work. Biomaterials is a fledgling field. It is a field the U.S. still leads in. We expect it to grow to a large industry as it impacts health care.

On the question of assessment between the various supports of research, it is difficult for me to provide you with an assessment, but I do want you to note the following. Since there are three different directorates involved in this program, it is clear to me there will be extensive discussion between them as to how to provide funding in this area. The report itself came out strongly in favor of funding the principal investigative grant, because that traditionally has been shown to produce the best results in this particular field. But principal investigators grants also include small research groups.

I should like to conclude by reminding you again that all indications point to the fact that materials science and engineering is a field that is on an exponential curve. There are wonderful opportunities to synthesize new materials, discover new phenomena, or combine materials in a hundred myriad ways to produce structures that will be useful to mankind. Our goal must be not only to ensure that basic research flourish but that in the case of materials science and engineering it does so in synergy with industrial and other strategic needs such as defense.

[The prepared statement of Dr. Chaudhari follows:]

Subcommittee on Science
Room 2318 - Rayburn House Office Building
Authorization Hearings for the NSF - March 13, 1991

TESTIMONY:

I am pleased to provide you my views on the NSF initiative in materials synthesis and processing in the context of the National Research Council report, "Materials Science and Engineering for the 1990's".

The study, which led to the academy report, was triggered by a letter from Don Fuqua to the president of the National Academy of Sciences. At the time Don Fuqua wrote to Frank Press, he was chairman of the House Committee on Science and Technology. Your committee's strong interest in materials has been a source of encouragement to a number of us to participate in this study, which took three years to complete and involved some five hundred scientists and engineers.

Amongst research fields Materials Science and Engineering represents a handful of fields that are unique in combining the generation of knowledge with application of knowledge. Recognizing this at the outset, our study involved a large number of senior technical management experts from eight major U.S. industries. Their views combined with those of researchers from universities and national laboratories was the basis of our findings and recommendations.

1. Advances in materials science and engineering are occurring world wide.
2. The United States is one of the lead players.
3. Advances in materials science and engineering are essential to all manufacturing industries in a competitive environment.
4. In order for the advances to be utilized in a timely manner, a strong coupling between those that generate knowledge and those that use it is required.
5. In the United States we must learn to couple knowledge and its use more efficiently if we are to compete in the world market. Our study found that our trading partners, including Japan and Germany, have not only targeted materials science and engineering as one of three fields to grow, but also integrated it in their national economic planning.
6. Within the field of materials science and engineering the United States is weak in synthesis and processing. Roughly speaking, synthesis and processing is concerned with making things. It involves, for example, preparing samples for scientific investigation, developing processes for fabricating inexpensive composites for the transport industry, or creating the knowledge base required for fabricating semiconductor chips and packages for the electronics industry.

The responsibility for correcting our weakness in synthesis and processing lies with the community. It is our intent in focusing on this area in the NRC study to inculcate in present and future materials scientists and engineers a cultural value for this area.

We need to do a number of things, but two are particularly important. First, we need to share with our colleagues at universities the intellectual challenges in synthesis and processing so that they can communicate these challenges in turn to their students. Second, we need to increase the research base in this area because it, more than any other aspect of materials science and engineering, combines both intellectual challenge and also a strong impact on industry. We are at an age where we can design and build new materials atom by atom or vastly improve processing of traditional materials by dynamic computer control and modelling.

The National Science Foundation is in a unique position to implement these changes. Its charter calls for developing human resources as well as scientific and engineering knowledge.

It is therefore appropriate and highly commendable that the NSF be the first agency to respond to the opportunities described by the National Research Council's materials science and engineering report. The way the NSF plan brings together the efforts of many different divisions is particularly noteworthy. Collectively, they have laid out a roadmap of progress for five years. They have contributed a base amount of $59M and are asking for an increment of $25M for this year. Both of these decisions are prudent and responsive to the recommendations of the materials science and engineering report. I personally support them completely.

The specific areas of electronics, photonics, and biomaterials have been identified for attention by the NSF. Electronics is the most mature of these three but it helps industry that is often characterized by relentless competition and progress. If all other factors are equal, progress in this field over the next decade will be determined by advances in synthesis and processing. Photonics, particularly optoelectronics, will be ubiquitous in the future. Combined with computers it will change our lives at home and at work. Biomaterials is a fledgling field. It is a field the United States still leads. We expect it to grow to a large industry as it affects health care.

It is difficult for me to provide you with an assessment of the appropriate balance between individual scientist projects, interdisciplinary groups, and instrumentation. All three are essential for progress in materials science and engineering. Given that a number of NSF directorates are involved in this initiative, I expect all three groups to receive attention and discussion.

I should like to conclude by reminding you again that all indications point to the fact that materials science and engineering is a field that is on an exponential curve: there are wonderful opportunities to synthesize new materials, to discover new phenomena, and to combine materials in myriad ways to build structures useful to mankind. Our goal must be to ensure not only that basic research flourishes but that, in the case of materials science and engineering, it does so in synergy with industrial and other strategic needs such as defense.

Dr. Praveen Chaudhari
IBM T.J. Watson Research Center
P.O. Box 218
Yorktown Heights, NY 10598

Mr. BOUCHER. Thank you.
Dr. Anderson?

STATEMENT OF DR. PHILIP W. ANDERSON, JOSEPH HENRY LABORATORIES OF PHYSICS, PRINCETON UNIVERSITY, PRINCETON, NEW JERSEY

Dr. ANDERSON. Thank you, Mr. Chairman. I am Philip Anderson. I am a Professor at Princeton: I am very glad to be called here before this committee, and I thank you gentlemen for giving me the opportunity to speak.

I come to you with somewhat ambiguous feelings. On the one hand, I agree with the other panel members that the materials initiative which you have before you is very much needed. In fact, if anything, it is too little too late. It surely should be supported on the basis that any alleviation of the present, rather desperate, situation in these fields, specifically in materials preparation and processing, is a good thing.

On the other hand, I see signs that the National Science Foundation has not necessarily identified its most pressing problems in this field, and has not necessarily come to terms with its historic inability to respond to the realities of science as it grows and changes.

For instance, the area in which I am personally working and the area I consider to be the most underfunded of all, and the most fertile in terms of results, stands to receive very little from this initiative. Perhaps it is something of a miscalculation that leads to me being here before you presumably to testify in favor of the program. I do not see much explicit recognition in this program of the kind of basic research on materials that I do.

Let me backtrack a little bit and tell you a little something about myself and where I am coming from. I am a theoretical physicist whose work has ranged across a wide variety of fields, but has focused mostly on condensed matter physics, which is the basic research agenda related to the science of materials, but it is not exclusively concerned with materials.

Funding condensed matter physics in particularly is one of the clearest win-win possibilities available to the Congress. This is epitomized by the career of the late John Bardeen, a condensed matter theoretical physicist—he did the same things I do—who died three weeks ago and was the only individual ever to receive two Nobel prizes in physics. One of these Nobel prizes was for a practical device, the transistor, which originated the now gigantic semiconductor industry.

The second prize was for the equally epoch-making theory which explains the phenomenon of superconductivity, a theory which has had very far-reaching consequences in the intellectual world, but is also indirectly related to the burgeoning industries founded on superconductivity. John Bardeen's career epitomizes this win-win character of this field. One can expect to make fruitful advances in fundamental, basic research which should be supported for exactly the same kinds of reasons you might support space science or LIGO or the SSC. Yet at the same time, there is always a possibility of the direct applicability of the results of this kind of research.

My own career also has these two aspects. For instance, I am a co-discoverer and holder of some of the fundamental patents on something called the Josephson effect, which is one of the most useful applications in the practical application of superconductivity. But I am also known as one of the co- discoverers of the Higgs phenomenon, in particle physics. One of the further consequences of the Higgs phenomenon for the understanding of basic science is one of the reasons why the Federal Government is spending $8.3 billion on the SSC.

It is always a mystery to me why it is that the Government considers one of my good ideas to be worth so very much more than all the others put together.

In spite of the fact that basic research in condensed matter physics has this remarkable double payoff, it has always been relatively poorly funded within the NSF relative either to basic research in other fields of physics such as nuclear, particle or atomic physics, as well as relative to applied work aiming at short-term goals, and it has been the object of several recent cuts.

A major difficulty in this field has been that for historical reasons the funding for basic physics research in the NSF comes from two separate divisions within the math and physical sciences directorate, namely the division of materials research and the division of physics. For instance, less than three years ago it became clear from the public statements of the director of the NSF that he was actually unaware that the division of materials research funded any basic physics research at all, since he was unaware that cuts in the division of materials research had affected theoretical physics. Basic physics has had to fight for its life within the division of materials research program, which itself has not been a high priority of the National Science Foundation.

Over the years condensed matter physics has been steadily cut back, relative to short-term applications as well as relative to other kinds of basic research. There is no explicit recognition of its role and no provision for redress of the recent cuts in this field included in the present proposals, although of course I am assured that the general health of the division of materials research would undoubtedly do everyone considerable good.

One of the most serious problems has been that the kind of basic research funded by the division of materials research has actually been a much more effective growth area than that in the physics division program, or even in the rest of the division of materials research. For instance, within this area great advances in the area of hydrodynamic turbulence have taken place. The field has made vital connections with biophysics, it has made vital connections with computer science in the growth area of neural networks; it has made vital connections with polymer science and with a host of other fields. Internally, it contains the growth field of high-temperature superconductivity, the science part of that field. There has been no change in funding to accommodate this growth.

Within the division of materials research, and I believe within the Government in general, there is a tendency for short-term goals to drive out long-term research. This could easily happen here if this initiative is accepted, but the funding levels are not sufficiently raised to accommodate it.

For these reasons, my feelings about what should be done include basically three points. First, I agree that one should support the initiative in materials preparation and processing, since indeed this is one of the great weaknesses in our materials research training effort. I also believe we should accept the emphasis on the individual investigator funding.

I think the committee should ask the National Science Foundation, and possibly the Science Advisors Office, the OSTP, to reexamine the structure of funding in the basic sciences in view of the amount of change and growth in science which has taken place since the National Science Foundation structure was set up. In particular, the restriction of the mandate of the physics division to the numerically relatively small fields of particular, nuclear and atomic physics should be reexamined. It should seem only fair that all kinds of basic physics be allowed to compete on the same level playing field.

Certainly, the physics which underlies the new industries of the future should not be the least well funded of all the fields of physics.

Finally, I think Congress, the Science Board and the National Science Foundation structure should keep in mind its mission to provide the basic research and the university infrastructure underlying the science and technology of the country. Because the National Science Foundation, through inadequate funding, has abdicated much of this role, we find some basic research funded by nominally mission-oriented agencies, such as DOE, NASA and DOD. In the end, these are relatively unreliable sources for basic research funding and one must keep in mind that our scientific infrastructure proper depends primarily on the National Science Foundation, and not try to convert the National Science Foundation into yet another mission oriented agency.

In the end, growth fields such as condensed matter physics really have nowhere else to turn but to the National Science Foundation. Some of the applied research included in this proposal could and is being done by industry and mission oriented agencies, while there is no increase in the National Science FOUndation's own unique role in basic research.

Let me close with a couple of true stories. One of the types of materials, for instance, which is being most heavily emphasized in this initiative is electro-optic materials. One of the best of the electro-optic materials I happen to know about. I know about its discovery very well. I was there in the Bell Laboratories some 40 years ago when it was discovered, and I was working closely with the group which discovered it. It was not discovered because someone was looking for electro-optic materials. It was discovered strictly as a consequence of fundamental, non-goal oriented basic research.

A second true story is that one week ago an experimentalist friend of mine at Princeton came to me with the news that he was rather desperate because one-third of his funding, which came from the Office of Naval Research, was to be cut off. As is true of most good condensed matter experimentalists, he has to make do with a patchwork of grants from several agencies in order to maintain a first-class laboratory. Indeed, I asked him about the National Science Foundation, and he said his National Science Foundation grant was basically a pittance which had been repeatedly cut, and he could not even maintain his equipment on his National Foundation Grant.

This man is one of the foremost researchers in the world, a person I would bet roughly 50-50 on to receive a Nobel Prize within the next five years. If his work is being strangled by the inadequacy of funding through the National Science Foundation, what is happening to people who are not at prize- winning levels?

Thank you.

[The prepared statement of Dr. Anderson follows:]

March 13, 1991
Rayburn House Office Bldg.
9:30AM, Room 2318

Testimony Before the Subcommittee on Science, Space and Technology

Philip W. Anderson
Joseph Henry Laboratories of Physics, Jadwin Hall
Princeton University, Princeton, N.J. 08544

I come to you with ambiguous feelings. On the one hand I am sure the materials initiative which you have before you is very much needed, in fact, it is too little and too late. It surely must be supported on the basis that any alleviation of the present desperate situation in these fields, specifically materials preparation and processing, must be good. On the other hand, I see little sign that the National Science Foundation has identified its most pressing problems, and come to terms with its historic inability to respond to the realities of science as it grows and changes. The area in which I, personally, am working, which I consider to be the most fertile in terms of results and the most underfunded of all, stands to receive relatively little from this initiative. It may be something of a miscalculation on someone's part which leads to my being here before you, presumably to testify in favor of the program.

Let me backtrack a bit and try to tell you something about who I am and where I am coming from. I am a theoretical physicist whose work has ranged across a wide variety of fields, but has focused mostly on condensed matter physics, which is the basic research agenda related to the science of materials. (But not exclusively concerned with materials.)

Funding Condensed Matter physics is one of the clearest "win-win" possibilities available to you. This is epitomized by the career of the late John Bardeen, a condensed matter theoretical physicist who died three weeks ago and was the only individual ever to receive two Nobel prizes in physics. One of them was for a practical device, the transistor, which started the now gigantic semiconductor industry on its way; the second, for the equally epoch-making theory which explained the phenomenon of superconductivity, a theory which has had very far-reaching consequences intellectually and is indirectly related to the burgeoning industries founded on superconductivity. Bardeen's career epitomizes this "win-win" character of this field; one can expect to make fruitful advances in fundamental, basic research which should be supported for exactly the same kinds of reasons which lead you to support space science and the SSC; yet at the same time there is always the possibility of direct applicability of the results of research. My own career also has these two aspects; I am, for instance, a codiscoverer and a holder of fundamental patents on the Josephson effect, one of the most useful devices in the practical application of superconductivity; but I am also known as one of the discoverers of the "Higgs phenomenon" in particle physics; and the further consequences of this phenomenon for our understanding of basic science are one of the major reasons why the U.S. government is spending 8.3 billion dollars on the SSC. It is a mystery to me why one of my ideas is worth so much more to the U.S. government than all the others.

In spite of the fact that basic research in condensed matter physics has this remarkable double payoff, it has always been poorly funded within the NSF relative either to basic research in other fields of physics such a nuclear, particle or atomic physics, as well as relative to applied work aiming at short-term goals, and it has been the object of several recent cuts.

A major difficulty has been that for historical reasons the funding for basic physics research in the NSF comes from two separate divisions, materials research and physics. For instance, less than 3 years ago it became clear from public statements of the director of the NSF that he was unaware that the DMR funded any basic physics research, since he was unaware that cuts in the DMR had affected theoretical physics. Basic physics has had to fight for its life within the DMR program, which itself has not been a high priority of the NSF. Over the years condensed matter physics has been steadily cut back, relative to short-term applications as well as relative to other basic research. No explicit recognition of its role and no provision for redress of the recent cuts in this field is included in the present proposals although, of course, general health of the DMR would do everyone some good. One of the most serious problems has been that the kind of basic research funded by DMR has been a much more effective growth area than that in the physics division program, or even than the rest of DMR. It is, for instance, within this area that great advances in the study of hydrodynamic turbulence have taken place; the field has made vital connections with biophysics, with computer science in the growth area of neural networks, with polymer science, and a host of other fields; and internally it contains the growth field of high-temperature superconductivity. But there has been no change in funding to accommodate this growth. Within DMR and, I believe, in government in general there is a tendency for short-term goals to drive out long-term research. This could easily happen here if this initiative is accepted but the funding levels are not generally raised to accommodate it. For these reasons, I recommend that this committee do three things.

(1) Support the initiative in materials preparation and processing specifically, since indeed this is one of the great weaknesses of our materials research and training, and also you should accept the emphasis on IIA funding.

(2) I think you should ask the NSF and possibly the OSTP to reexamine the structure of funding in the basic sciences in view of the amount of change and growth in science which has taken place since the NSF structure was set up. In particular, the restriction of the

mandate of the physics division to the numerically relatively small fields of particle, nuclear and atomic physics should be reexamined. Perhaps all basic physics should compete on the same level playing field.

(3) I think Congress, the Science Board and the NSF structure should reexamine whether NSF has lost sight of its mission to provide the basic research and the university infrastructure underlying the science and technology of the country. Because the NSF has abdicated much of this role, we find some basic research funded by nominally mission-oriented agencies such as DOE, NASA and DOD. But in the end these are unreliable sources for basic research funding and one must keep in mind that our scientific infrastructure properly depends primarily on the NSF, and not try to convert NSF into yet another mission-oriented agency. In the end, growth fields such as condensed matter physics really have nowhere else to turn than NSF. Much of the applied research included in this proposal could and is being done by industry and mission agencies, while no increase in NSF's own unique role is provided for explicitly.

Let me close with a true story. One week ago an experimentalist friend of mine came to me with the news that he was desperate because the 1/3 of his funding which came from ONR was to be cut off. As is true of most good condensed matter experimentalists, he has to make do with a patchwork of grants from several agencies in order to maintain a first-class laboratory; indeed, I asked him about NSF and he said that his NSF grant was a pittance which had been repeatedly cut and would not even allow him to maintain his equipment. This man is one of the foremost researchers in the world, a person I would bet 50-50 on to receive a Nobel prize within the next 5 years. If his work is being strangled by the inadequacy of funding, what is happening to people who are not at prize winning level?

Mr. **Boucher**. The Chair thanks each of the panelists for the presentation this morning.

Dr. Anderson, let me begin with you. You have suggested that within the funding by the National Science Foundation of research in physics that there is not an appropriate distribution of research monies within the various subfields of physics. That leads me to the question of whether the physics community generally has attempted to affect in any significant way the funding priorities at the National Science Foundation with regard to physics generally.

The reason I ask that question is because our impression here is that there is a great deal of interaction between the NSF and the research communities, and that advice is constantly being sought as to priorities that should receive funding. I wonder if you could generally comment on the extent to which the physics community is being consulted, and whether that community has in any major way tried to affect the funding priorities at the NSF.

Dr. **Anderson**. I think I addressed that a little bit in my testimony. Of course, to some extent this is a deduction from the way things work. But as I said, there are two divisions that fund physics research. If one convenes an advisory committee, one of them will be for this one half of physics, and the other one will be a materials science advisory committee, which will contain some physicists, but also some ceramicists, some chemists, and metallurgists—many other people. Across this boundary, there has been very little overall discussion. I am not familiar with this advisory apparatus. I have never been asked to serve on any of these committees for some reason, perhaps because my opinions occasionally tend to call things as I see them.

I have never been asked to serve on any of these advisory committees. Therefore I can't talk from personal experience. But these are two sets of committees, and they have different goals and they consist of very different kinds of people.

Within the physics division, there would tend to be a nuclear physics advisory committee, and a particle physics advisory committee, an atomic physics advisory committee, and these people would feel very delicate, probably, in many cases, appropriately so, about commenting on their neighbors' bailiwick.

On the other hand, I think the American Physical Society has recently quite seriously been discussing somewhat heatedly within the Council the question of actually setting priorities across fields. Historically, it has been very hard to compare one field with another field. I think before doing so, one needs to set up some criteria for doing so. One of the things which is very obvious to those of us who go around visiting universities and so on is that some fields, for instance, are attracting new graduate students, and some fields are not. One could set that up as part of the criteria. Some fields have a very high level of funding per active research scientist, and some have a lower level of funding, one could make that kind of comparison.

Although I think the comparisons are possible, I think many scientists are reluctant to do so, and properly so, because you always know the opportunities in your own field better than those in some other field. But I think there is a serious problem that it is almost impossible to set priorities across organizational lines.

Mr. **Boucher**. Let me get each of the panelists to comment on the appropriateness of the allocation of resources within this new initiative itself, in materials science. Do we have the correct balance in terms of a number of categories, specifically student support and instrumentation needs and is the balance correct between basic research and physics and research and materials engineering?

Dr. Economy, we could begin with you, sir.

Dr. **Economy**. With respect to the $25 million initiative, this is all intended for individual investigators, or small groups, so that very little would be available for instrumentation other than the fact that the grant size may be perhaps 30 percent larger than the average grant size for individual investigators. So the scientist would have a little flexibility to construct equipment with the extra 30 percent.

The issue of balance between physics and chemistry, I think the focus in the synthesis and processing is intended to encompass a half dozen theme areas, including the metals, ceramics, polymers, and so on, composites, electronic materials, and the hope would be that scientists that are working in these areas that are training students in these areas would have the potential to work and learn new phenomena and design materials with new properties, because indeed they are working at interfaces between areas.

This has never occurred in the past. We have never had an educational program that has focused the attention of students on a breadth of education. Typically industry would take people that were trained in chemistry then educate them in polymers or metals, and so forth, in the industrial world.

But here I think we have something quite different happening, which I feel will have major implications in the design of new and revolutionary materials.

Mr. **Boucher**. Do you have any recommendations for us as to how we might reallocate the resources within this initiative, or do you think they are properly balanced as they stand?

Dr. **Economy**. I think they are properly balanced. I think the first year's emphasis, as Dr. Chaudhari pointed out, was on photonic, electronics, biomaterial and bimolecular materials. I think it is a matter of balance where these four areas have not been funded effectively. I think in succeeding years, the program will broaden in terms of its focus.

Mr. **Boucher**. Thank you. Dr. Chaudhari?

Dr. **Chaudhari**. I think the materials research activity in general has to be strengthened in the United States. That include physics, chemistry, metallurgy, ceramics, polymers. When we looked at that activity in the United States, we recognized that it needs to be strengthened across the base. The reason we focus on synthesis processing is simply because it was the weakest of all the activities in materials science and engineering. That was point number one.

Point number two was it couples most closely with manufacturing industry. It is not manufacturing. Manufacturing is more than this. But it does couple with that effectively. So our feeling was that we needed to strengthen this area, not at the expense of other areas in materials. We think that ought to be strengthened. But this being the weakest, we focused on that. It is important to keep that in mind.

Secondly, we feel this coupling between industry and academia can be strengthened using this particular initiative. In that sense, with that large scale response, I think what the NSF is doing is the right thing. They have a long-term program, it is a five-year program. What they have come forward with this year are some specific initiatives out of that five-year program. If you view it in that sense, what they are doing is the right thing, starting off the right way.

Mr. BOUCHER. I take it from your comment that the private sector contributed in a significant way to the establishment of these resource allocations, so that the research that is conducted would have some benefit further down the road in terms of industrial application?

Dr. CHAUDHARI. Yes, in fact what I would insist we consider is that a lot of the funding in these areas, not so much in basic research, but as you get closer to engineering, that the industrial partnership be formed. Not only be formed, but they bring their own money to the table. There is nothing like money to make sure to get their interest.

Mr. BOUCHER. Thank you very much. Dr. Anderson?

Dr. ANDERSON. In the first place, I do want to say that I was trying to be very careful not to testify against this initiative, because in particular I agree very strongly that of all the problems we have. Perhaps the worst is materials processing and synthesis. We do not have enough people who can make good single crystals, etc., good films, etc. There is no question but that is a big weakness in this country and has been for many years.

Insofar as I was negative, I was disturbed by—there is a kind of matrix funding going on here. There is a funding in terms of fields, and funding in terms of materials. Here the focus is on picking out specific materials. That is a good thing to do if you are thinking about industrial applications and not necessarily a good thing to do if you are thinking about the structure of science. Science does not distinguish the types of materials.

But in fact there is flexibility here. I would like to see as much flexibility as possible being left within this program as a whole, so that good project officers—and the project officers in the NSF, in my experience, are very good—a good project officer can judiciously fund a certain amount of relevant basic science. That happens all the time and it is very good.

Let me say about your question about industry that although I am a basic scientist, I spent 35 years in industry. My grant with the National Science Foundation has been for a long time a joint industry-university grant. So I am entirely aware of and sympathetic with the needs of industry as well.

Mr. BOUCHER. The Chair thanks each of these witnesses.

The gentleman from Illinois, Mr. Bruce.

Mr. BRUCE. Dr. Economy, I was intrigued by your testimony and Mr. Boucher has covered some of the areas I wanted to cover also. You say the materials industries, the current status is chaotic, France, Germany and Japan have got some sort of program, a 10-year program in Japan and they are starting their second 10 years.

What is the problem in the American scientific community and the United States Government that allows us or causes us to have a chaotic relationship, or chaotic situations in materials research?

I ask that realizing that at the University of Illinois we have a composite materials research center there for $27 million outlay, the nondestructive materials research lab, we seem to, at that particular university, use the taxpayers' money fairly wisely and in fairly large quantities, to establish a research center. Are we the exception at the University there? What is the problem that we cannot develop within the scientific community, within the National Science Foundation, a coherent materials policy?

Dr. ECONOMY. Yes, I think we have been fortunate at the University of Illinois in terms of these large centers. Often, since the composite center, the industries have joined because there is a large central funding from the Navy, for example. So they are getting the advantages of a core funding program and participating and getting that kind of synergism. The issue of industry and what the NSF can do to impact industry, though, they are almost separate questions.

In other countries such as Japan, Germany and France or Great Britain, too, the government plays a very strong role in influencing industry's posture. How it expends its monies on R&D. This is certainly very true in Japan. This is not the case in the U.S. I think industrial leaders have a lot of independence in terms of selecting the way they will expend their monies, whether it will be for R&D or for acquisitions. I think you can see this most clearly in the role of Wall Street.

I think Wall Street is probably the only audience that the industrial leaders will pay much attention to, because it is there where the price earnings ratios may very well be determined, where the value of their stocks and bonds are essentially assessed, and so forth. And there was an era, perhaps in the mid-1950s, when Wall Street was enamored with materials R&D. Whenever a company would announce that they were going to hire 50 Ph.D.s, the stock would move right up.

But Wall Street changed its posture, starting in the late 1960s, and really emphasized near-term profits. I think that situation has persisted. We can do all we want with the NSF to try to improve the infrastructure, and we will. We will be producing a product that does not exist, a student that go into industry and generate new materials and advanced processes, and so on. But we still have to deal with that one problem of getting industry's total commitment to competing for the future as other countries have already achieved.

Dr. CHAUDHARI. I won't comment on the structural changes, financial and otherwise, but I do want to observe two points. First, the United States culturally has relied more on independent entrepreneur spirit where they compete. As we see competition from the outside, we are beginning to realize the value of talking to each other and saying there are common generic bases of research on knowledge that we can generate collectively, which we can then take and compete in the marketplace.

This recognition is more and more obvious and discernible. I think it is beginning to play a role. For example, the way we collected information for the study; we asked the aerospace companies, collectively, to tell us what the aerospace industry needs. We did the same with the electronics industry, we asked TI and Bell Labs. They were willing to share this information and come forward. We are beginning to do this at a different level. We are getting people from national labs, from universities, from industry, to get together in a given area and ask what it is we think our goal should be in a given area.

I think we need to encourage the latter much more than we have done in the past. The National Science Foundation initiative is much more confined to the NSF, but I think on a national scale, we eventually will have to get together with all the other agencies and look at plans and materials research on that U.S. perspective rather than on an agency perspective. That part is still going on in real time, so to speak.

Mr. BRUCE. Thank you, I have nothing further.

Mr. BOUCHER. The Chair thanks the gentleman and extends thanks to this panel for a very thought-provoking and interesting series of statements. We will consider your comments as we further review the National Science Foundation's fiscal year 1992 budget request. We may have some additional questions for you, in which case we will submit those in writing.

If you have additional recommendations for us along the lines we have discussed this morning, for allocation of the resources within the materials science initiative, in a way that differs from the NSF's allocation, on reflection, if you care to submit those to us, we will be happy to receive them. We will keep the record of this hearing open for a period of 10 days for that purpose.

The Chair thanks these witnesses, and this hearing stands adjourned.

[Whereupon, at 12:54 p.m., the subcommittee adjourned, to reconvene at the call of the Chair.]

APPENDIX I

GEORGE E. BROWN, Jr., California, CHAIRMAN

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JOE BARTON, Texas
DICK ZIMMER, New Jersey
WAYNE T. GILCHREST, Maryland

RADFORD BYERLY, Jr.
Chief of Staff
MICHAEL RODEMEYER
Chief Counsel
DAVID D. CLEMENT
Republican Chief of Staff

March 6, 1991

Dr. Frederick M. Bernthal
Deputy Director
National Science Foundation
1800 G Street NW
Washington, DC 20550

Dear Dr. Bernthal:

Thank you for your informative testimony on February 20, 1991 concerning the National Science Foundation (NSF) budget request and program plans for fiscal year 1992. In order to complete the hearing record, we would appreciate receiving your responses to the following additional questions:

1. Does NSF have any suggestions for improving the statutory language regarding administration of the Robert Noyce Scholarship Program?

2. What problems, if any, does NSF currently have in filling personnel slots for program officers, including both permanent employee slots and also rotator slots? Has there been any deterioration in the qualifications of individuals applying for positions at NSF?

3. Since international interest exists in LIGO, why has the initial stage of building the first two detectors not been proposed as a collaborative undertaking with a foreign partner?

In addition to responses to the preceding questions, please provide a summary of NSF programs that support educational activities at two-year colleges, including programs not funded at two-year colleges but which affect two-year colleges.

I appreciate your attention to this request. Your reply will be included in the printed hearing record.

With kind personal regards and best wishes, I remain,

Sincerely,

Rick

Rick Boucher, Chairman
Subcommittee on Science

RB/Weg

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
DIRECTOR

April 10, 1991

Honorable Rick Boucher
Chairman
Subcommittee on Science
Committee on Science, Space,
and Technology
U. S. House of Representatives
Washington, DC 20515

Dear Mr. Boucher:

Thank you for your letter of March 6, 1991, regarding NSF plans for Fiscal Year 1992. I am pleased to present the Foundation's responses to your questions regarding specific NSF programs.

I look forward to working with you in the future.

Sincerely,

Walter E. Massey
Director

Enclosure: Questions/Answers for the Record from
Congressman Rick Boucher

QUESTIONS FOR THE RECORD
FROM CONGRESSMAN RICK BOUCHER

ADMINISTRATION OF ROBERT NOYCE SCHOLARSHIP PROGRAM

QUESTION: Does NSF have any suggestions for improving the statutory language regarding administration of the Robert Noyce Scholarship Program?

ANSWER: The Noyce Scholarship Program has an important objective that the Foundation supports: to help encourage more of our young people to pursue careers as elementary or secondary school teachers of mathematics or science. There is no doubt that improved teacher preparation is an important part of any comprehensive effort to improve our math and science education enterprise. However, as currently written, the Noyce program would have NSF transfer some of its own scarce resources for education and human resources to the Department of Education for obligation and management. NSF would prefer that its education and human resources remain with the Foundation so that program quality and management accountability can be maintained.

In addition, the program requires a substantial amount of effort to enforce the service requirements and manage any required repayments that might be necessary from awardees. The Foundation, were it to have responsibility to implement this program as currently described in the statute, is ill-equipped to handle the service and repayment provisions. Thousands of awardees would have to be tracked by the Foundation to ensure that each has met his or her specific service requirement, and legal action would have to be instituted against those who have not. Finally, the program would duplicate a broad range of existing programs (e.g. Paul Douglas Scholarships, Education financial aid programs, etc.) that support the training of math and science teachers.

RECRUITMENT OF NSF PROGRAM OFFICERS

QUESTION: What problems, if any, does NSF currently have in filling personnel slots for program officers, including both permanent employee slots and also rotator slots? Has there been any deterioration in the qualifications of individuals applying for positions at NSF?

ANSWER: NSF has been experiencing problems with recruitment of program officers (both permanent and rotational) for a number of years. Our problems are especially serious because we recruit primarily at senior levels. Over the past few years both industry and academic salaries for senior scientists and engineers have outpaced government salaries. We have been able to maintain the quality of our staff in part by extensive recruiting, by offering jobs that we believe are challenging and meaningful, and by use of flexible mechanisms such as the IPA program.

A number of recent legislative changes will provide additional flexibilities. The "rotator amendment" that the Congress passed in 1988 allowed us to pay benefits such as per diem and health and life insurance directly to rotators' (now called "visiting scientist") home institutions or retirement plans. Nonetheless, the salary limit was still too low to attract many senior scientists and engineers from either industry or academia.

Two recent legislative initiatives, however, auger well for the future. The recent increase in SES salaries will enhance our ability to recruit at senior management levels, such as division directors. For program officers, pay reform legislation that the Congress passed last year will be of great benefit. As salaries over the next 10 years adjust to a local market rate, we expect government jobs in the Washington, D.C. area to command higher salaries and thus help in recruiting. Likewise, flexibilities to allow recruitment and retention bonuses will help.

We are grateful to the Congress for these very important changes in the Federal pay system, and look forward to their full implementation.

INTERNATIONAL COLLABORATION FOR LIGO

QUESTION: Since international interest exists in LIGO, why has the initial stage of building the first two detectors not been proposed as a collaborative undertaking with a foreign partner?

ANSWER: NSF tried to initiate a form of collaboration with the Europeans, in which they would have provided one detector while the U.S. would have supplied the other, maintaining both under the strong central management needed for a successful project. This suggestion was advanced by both the NSF and the Director of the LIGO project, but rejected by the European scientists and their funding agencies. The reasons for this were due in part to the fact that European planning activities were already at an advanced stage, and a reduction from two to one facility there was viewed as a step backward. Moreover, as construction funds were coming in part from funding agencies' budgets for ground-based astronomy, the goals of the funding agencies involved required that there be at least three detectors worldwide operating in a coherent network in order to get precise data on source location.

Over the past few years, discussions about international collaboration with European teams have been ongoing. These have led to the current understandings to work together in areas of common scientific and technological interest while planning for eventual joint observations during the astronomy phase.

In addition to ongoing high-level discussions, there has been a continuing series of international cooperative activities at the level of working scientists. There have been open exchanges of technical information, long-term and short-term research visits, international conferences, etc. In addition, a plan has been developed for areas of cooperative R&D on specific areas of mutual interest. This is being done via participants from all the U.S and European teams working in smaller groups on: Data Analysis and Simulation; Control Systems Design; and Optical Systems Modeling.

NSF SUPPORT FOR TWO-YEAR COLLEGES

QUESTION: Please provide a summary of NSF programs that support educational activities at two-year colleges, including programs not funded at two-year colleges but which affect two-year colleges.

ANSWER: In FY 1990 the Foundation awarded to two-year colleges 71 educational grants totalling $3.84 million. The majority of these grants (53 awards, $1.85 million) were from the Instrumentation and Laboratory Improvement Program. The Career Access Program also had a significant contribution with 5 grants totalling $1.17 million. The various precollege programs awarded to two-year colleges 12 grants totalling $800,000.

In addition to these awards, there are several other activities that provide direct benefit to the two-year colleges:

- Over half of the Undergraduate Faculty Enhancement awards include specific components for two-year colleges;
- The new Alliances for Minority Participation awards will each feature significant participation by two-year colleges as part of the alliances;
- NSF participates in numerous outreach activities to disseminate information and assist two-year college faculty and administrators.

APPENDIX II

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
DIRECTOR

FEB 14 1991

February 11, 1991

Honorable George E. Brown, Jr.
Chairman
Committee on Science, Space, and Technology
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Section 14 (j) of the National Science Foundation Act of 1950 (42 U.S.C. 1873) (j) requires the Foundation to submit to Congress a three-year budget estimate which includes estimates for each major activity, each scientific directorate, the Education and Human Resources Activity, the United States Antarctic Program, Academic Research Instrumentation, Salaries and Expenses (formerly called Program Development and Management), and Office of Inspector General. These estimates are contained in the attachment to this letter.

The estimates for Fiscal Years 1993 and 1994 indicate continued support for the programs and initiatives set forth in the Foundation's budget request for FY 1992.

Sincerely,

Frederick M. Bernthal
Acting Director

Attachment: NSF Funding Estimates for Major Activities, FY 1992 - 1994

NATIONAL SCIENCE FOUNDATION
Funding Estimates for Major Activities
FY 1992--1994

(Dollars in Thousands)

Activity	FY 1992 ESTIMATE	FY 1993 ESTIMATE	FY 1994 ESTIMATE
Biological, Behavioral, and Social Science	355,640	410,000	469,000
Computer and Information Science and Engineering	229,500	265,000	303,000
Engineering	247,700	285,000	327,000
Geosciences	419,540	484,000	554,000
Mathematical and Physical Sciences	650,080	749,000	858,000
Scientific, Technological and International Affairs	61,040	70,000	81,000
Subtotal, Research and Related	$1,963,500	$2,263,000	$2,592,000
Education and Human Resources	390,000	415,000	438,000
U.S. Antarctic Program	193,000	210,000	227,000
Academic Research Instrumentation	50,000	50,000	50,000
Salaries and Expenses	122,000	126,000	132,000
Office of Inspector General	3,500	4,000	5,000
Total NSF	$2,722,000	$3,068,000	$3,444,000

APPENDIX III

NATIONAL SCIENCE FOUNDATION
WASHINGTON D.C. 20550

OFFICE OF THE
DIRECTOR

December 31, 1990

Honorable Robert A. Roe
Chairman
Committee on Science, Space,
and Technology
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

This report responds to House Report 101-309, Oversight of the National Science Foundation Fiscal Year 1990 Programs.

The Committee on Science, Space, and Technology requested that the National Science Foundation provide a report on planning, priority-setting, and management procedures for national research facilities.

Sincerely,

Frederick M. Bernthal
Acting Director

Enclosure: Report on Facilities Planning at the National Science Foundation

Identical letter sent to the following :
Honorable Robert S. Walker
Honorable Edward M. Kennedy
Honorable Orrin G. Hatch
Honorable Ernest F. Hollings
Honorable John C. Danforth

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A REPORT TO THE
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

FACILITIES PLANNING AT THE NATIONAL SCIENCE FOUNDATION

Summary

Planning for specialized research facilities is an integral part of the National Science Foundation's overall process for planning and priority-setting. Facilities priorities are driven predominately by research opportunities and requirements. Opportunities for facilities are carefully balanced with the needs of individual researchers. Facilities plans receive extensive review and discussion before any funding is approved. Costs are closely monitored by Foundation staff.

In FY 1990, NSF support for specialized research facilities totalled almost $400 million, or 19 percent of the Foundation's budget. About 25 percent of this are capital costs, with the balance used for operations. Current Foundation projections call for facilities support to increase to approximately $620 million by FY 1995.

Context

The House Committee on Science, Space and Technology requested in its Oversight Report of NSF Programs (H101-309) that it:

> would like to become more familiar with the planning process at NSF for support of national research facilities ... The Committee requests that NSF prepare by December 15, 1990 a review of long-range plans for major upgrades and new construction, as well as projections for operating budget levels for national facilities over the next three to five years. The Committee would like to know how NSF establishes priorities for facilities construction and what management procedures are in place for tracking and estimating facilities costs.

Introduction

Planning for specialized research facilities is integrated into the Foundation's overall process for planning and priority-setting. A recent report to the Committee on Science, Space and Technology entitled "Planning and Priority-Setting in the National Science Foundation" described NSF's general planning process (Appendix I). The mechanisms described in the report apply to specialized research facilities as well as to other types of support provided by the Foundation.

Two key factors affect facilities planning. First, in recent years the Foundation's priorities have been, in order of importance, people, instrumentation, and facilities. NSF's budget requests to Congress have included a balanced portfolio of programs reflecting these priorities. However, with reductions in the Foundation's appropriations from the requested levels, the Foundation has chosen to protect support for people within its research, education, and human resources activities, and thus has been able to provide less support for instrumentation and facilities than planned.

Second, the increasing needs for funding for operations and maintenance of existing facilities and the deferral of much needed new facilities are imposing growing pressures on the Foundation. These pressures are a consideration in current facilities planning activities.

Types of Specialized Research Facilities

Specialized, multi-user research facilities supported by NSF include astronomical observatories, oceanographic research vessels, supercomputing and high-speed networking facilities, and facilities for physics, atmospheric sciences, materials science, and engineering. The Foundation also supports the specialized facilities required for the operation of the U.S. Antarctic Program including airplanes, helicopters, research vessels and icebreakers.

Many of these facilities have been supported by the Foundation since the 1960s. Others, such as NSFNet and the supercomputing centers, are comparatively recent undertakings and respond to the evolving needs of the research community.

Major new facilities initiatives over the last decade include the Very Long Baseline Array (VLBA), the Advanced Scientific Computing centers, NSFNet, the Green Bank Telescope, an oceanographic research vessel to replace the aging R/V/ CONRAD, and the acquisition of a research vessel with icebreaking capabilities for use in the Antarctic. New facilities planned include two 8-meter optical/infrared telescopes, the National High Magnetic Field Laboratory, and the Laser Interferometer Gravitational Wave Observatory (LIGO).

The Planning Process

Planning and priority-setting for all of the Foundation's programs is a process that is continuous, open, and decentralized. Opportunities for forefront research, the development of innovative technologies, and the needs of researchers are all major considerations in the planning process. The scientific and engineering communities serve as major sources of information and ideas.

Planning and priority-setting for research facilities involves selecting from among many exciting ideas those to be emphasized in particular programs and budgets. Priorities are reflected in the differential rates of budget growth for various programs and in the balance of funding between facilities and other Foundation programs. Choices explicitly take into account:

- scientific readiness;
- technical feasibility;
- response to national needs;
- capital and operating costs;
- the needs of and impact on small-scale, individual researchers;
- capabilities of other facilities funded by NSF and other agencies;
- international partnerships; and
- international competitiveness.

Proposed facilities receive extensive discussion and review at all levels of the Foundation before any funding is approved. Each NSF division and directorate undertakes its own internal priority-setting exercises, including input from external scientific advisory committees or from panels of the National Academy of Sciences or National Academy of Engineering. The NSF Director and senior staff formulate Foundation-wide priorities, focusing on the most promising opportunities and balancing the various needs of the directorates against the available funds. These plans are presented to the National Science Board, which establishes policy for the Foundation, for review and approval.

The establishment of priorities and the decision to construct new facilities can be a lengthy process. For example, the two new 8-meter optical/infrared telescopes currently being planned have been under discussion since at least 1980.

- In its recommendations for astronomy for the 1980s, issued in 1980, the National Academy of Sciences' Astronomy Survey Committee strongly advocated a program of technology development leading to advanced ground-based optical/infrared telescopes.

- A committee subsequently formed by the National Optical Astronomy Observatories (NOAO) considered future directions for national night-time astronomy, and concluded that new large telescopes would be essential for future developments in astronomy.

- In the mid-1980s, NOAO began research on the technologies needed for the development of large telescopes and developed its five-year plan for astronomy facilities, including plans to construct two 8-meter telescopes. Extended discussion within the astronomy community helped NOAO refine these plans and helped develop a consensus that these telescopes were a national priority for astronomical research.

- After extensive discussion with Foundation staff, NOAO submitted its initial proposal for the telescopes in September 1989. The proposal was thoroughly reviewed by outside experts.
- The National Science Board was informed of the plans for the two telescopes in the winter of 1990, including the Foundation's intention to collaborate with international partners. Negotiations with potential international partners are proceeding.
- In the spring of 1990, the Foundation's Advisory Committee for Astronomy issued a report highlighting the 8-meter telescopes as a priority for funding. In determining this priority, the Advisory Committee balanced wishes to increase funding for individual investigators and for instrumentation development with a view that these telescopes are important for the long-term vitality of the discipline.
- Initial funding for the design and construction of the two telescopes was included in the FY 1991 Budget Request to Congress.

Future steps in this planning process include formulation of a project development plan, preparing an environmental impact statement, signing Memoranda of Understanding with international partners, and approval of an award by the National Science Board.

The time scale described above is not at all unusual. From inception of a facility to its completion sometimes takes as much as ten to twenty years. Planning for the Very Long Baseline Array (VLBA) started in the mid-1970s, and the facility will be completed in FY 1992. Research necessary for the development of LIGO has been funded for almost a decade, and completion of that facility is planned for the mid 1990s. Since these facilities are designed for a lifetime of thirty years, initial planning activities may have implications for fifty years worth of funding for facilities development and use.

Funding for Specialized Research Facilities

Support for specialized research facilities totalled $394 million in FY 1990, approximately 19 percent of the Foundation's budget. This percentage has remained fairly stable over the last few years. About 75 percent of these funds are used to support operations, and about 25 percent are used for capital costs.

Table 1 shows Foundation support for specialized research facilities for FY 1987 - FY 1990.

Table 1.
Facilities Support at NSF
(Millions of Dollars)

	FY 87	FY 88	FY 89	FY 90
Capital Costs	82.6	91.2	97.7	104.6
Operating Costs	253.5	259.1	276.7	289.4
Total	336.1	350.3	374.4	394.0
Percent of NSF Budget	21%	20%	20%	19%

Table 2 shows the Foundation's planned support for specialized research facilities for FY 1991 - FY 1995.

Table 2.
Planned Support for Facilities
(Millions of Dollars)

	FY 91* Est.	FY 92 Est.	FY 93 Est.	FY 94 Est.	FY 95 Est.
Capital Costs					
Major Upgrades	87.5	98.2	95.3	110.5	127.5
New Construction	148.6	86.0	80.0	78.0	25.0
Operating Costs	314.1	357.5	392.4	422.1	468.1
Total	550.2	541.7	567.7	610.6	620.6

* Based on FY 1991 Request to Congress

These estimates are based on the Foundation's FY 1991 Budget Request to Congress. Changes to these funding requests will result in inflationary cost increases and lengthened construction schedules.

Projects included under "New Construction" are:

- Green Bank Telescope,
- two 8-meter optical/infrared telescopes,
- National High Magnetic Field Laboratory (NHMFL),

- Very Long Baseline Array (VLBA), and
- Laser Interferometer Gravitational Wave Observator (LIGO).

All $69.5 million for construction of the Green Bank Telescope appears in FY 1991 due to its special appropriation. Completion of construction of the VLBA is planned for FY 1992. Capital costs for LIGO, the two 8-meter telescopes, and the NHMFL continue through FY 1995.

"Major Upgrades" includes new vessels for the oceanographic fleet, the Advanced Scientific Computing centers, and NSFNet, as well as upgrades for other existing research facilities such as the radio telescope at Arecibo, Puerto Rico. Without these upgrades, the quality of research that can be performed at these facilities will deteriorate.

Proposed funding for facilities is increasing because of the new facilities planned, the needed upgrades to existing facilities, the increasing technological complexity of research facilities, and the increasing costs of construction and operations. Further, additional opportunities for new facilities may well develop over the next few years in response to research advances, adding to the existing estimates. Long-range estimates are that facilities will continue to account for approximately 20% of the total Foundation budget.

Largely because of these increasing costs, the Foundation is experimenting with new methods of budgeting for capital expenditures. Historically, both capital and operating costs for a facility have been included within the appropriate discipline's budget. However, the incremental funding required for major capital items is often too large for a single discipline's budget.

A new subactivity, Major Research Equipment, was establish in FY 1990 to support the construction of new, high-priority large-scale research facilities in the physical sciences. Projects budgeted within the Major Research Equipment subactivity are LIGO, NHMFL, the Green Bank Telescope, and the two 8-meter telescopes. All other specialized research facilities continue to be budgeted within the disciplines. The availability of sufficient funding for operations for both new and existing facilities is of increasing concern, and is being specifically addressed in NSF's long-range plans.

Leveraging

A strategy that the Foundation has successfully used to deal with the increasing costs of specialized research facilities is leveraging. Leveraging allows NSF funds for a project to be matched by funds from other sources such as state and local governments, universities, industry, and other federal agencies. Leveraging offers opportunities for expanded outreach, and cooperation, as well as optimizing the use of NSF funds.

Leveraging does have some associated disadvantages, such as the need for additional time to coordinate funding arrangements, and some fields of science and engineering may not attract outside support. However, the prestige of an NSF award often enables recipients to raise additional funds from other sources. For example, facilities including the Advanced Scientific Computing supercomputing centers and NSFNet receive substantial industry support. NSF funding for the new National High Magnetic Field Laboratory will be augmented by $58 million support from the State of Florida. NASA is joining with NSF in a joint effort to upgrade the Arecibo Observatory's 305-meter telescope.

International Considerations

NSF is increasingly turning to international partnerships as a way of financing new facilities. The Foundation has successfully entered into such partnerships in the past. For example, the Ocean Drilling Program, established in FY 1983, is jointly supported by the U.S. together with six international partners (soon to be seven with the addition of the U.S.S.R.).

The Foundation hopes that these types of partnerships will continue in the future. For example, the construction of the two new 8-meter optical/infrared telescopes is being planned as an international collaboration, with the United Kingdom and Canada as prospective partners.

Other projects, conceived as NSF-funded facilities, are planned to be coordinated with facilities in other countries in an effort to expand their abilities and extend their usefulness. For instance, the Laser Interferometer Gravitational Wave Observatory (LIGO) will be coordinated with two European facilities of technically compatible design in a cooperative effort to open the field of gravity wave astronomy. LIGO and the European facilities will jointly provide the geographic dispersion required for locating the source of a gravitational wave signal.

In fields with potentially strong ramifications for economic development and international competitiveness, the Foundation plans to develop and support new facilities as strictly U.S. efforts, without soliciting international partners. The new NSF-funded National High Magnetic Field Laboratory will keep the U.S. at the forefront of high magnetic field research.

Management Procedures for Tracking Facilities Costs

A number of Foundation procedures insure the accurate and complete tracking of the capital and operating costs of specialized research facilities. Internal planning for these facilities draws on the considerable NSF staff expertise developed through past facilities planning activities, as well as on the advice of external panels.

Facilities proposals receive extensive merit review, often including both mail and panel review, by scientists with expertise in the appropriate fields and/or with other major facilities. Independent cost estimates may be obtained to verify estimates provided in proposals. Plans for major facilities often go through several iterations, providing opportunities for refining designs and budget estimates.

Unsatisfactory merit reviews may provide the justification for the Foundation to modify or terminate support for facilities that fail to meet stated goals. More often, facilities have been terminated for other reasons such as age, technical obsolescence, or the changing requirements of forefront research. The Foundation has ended support for several facilities within the last few years. For instance, support for the John Von Neumann supercomputer center at Princeton University and for the low energy electron accelerator at the University of Illinois have both been phased out.

The Foundation relies on its awardees to monitor costs and operations of facilities projects, and to report on their progress. Awardees work closely with the NSF Program Managers for their facilities.

Program Managers within the cognizant NSF divisions hold much of the responsibility for oversight of NSF's specialized research facilities. These Program Managers provide guidance for the research facilities in their disciplines regarding the Foundation's major research thrusts, funding strategies, long-range priorities, and expected availability of funds. Program Managers review proposed annual program plans and long-range plans, review and evaluate the scientific and administrative performance of the research facilities, and recommend and justify proposed funding awards to these facilities. Program Managers use site visits, interim reviews, and annual reports for information, oversight, and monitoring facilities budgets.

In addition, the Foundation has several offices which exercise oversight over facilities programs and their funding. The Office of Budget and Control (OBAC) annually develops a formal financial plan for each program, including programs that support research facilities, that is consistent with the direction given by the National Science Board, Administration policy, and Congressional guidance. During the year OBAC program and financial staff monitor the funds planned for facilities programs and review program progress through consultation with program officers and through site visits.

The Division of Grants and Contracts is responsible for planning, negotiation, award, administration and oversight of NSF's specialized research facilities in conjunction with the cognizant program office. Depending on the type of center, these functions may include issuing solicitations, negotiating annual budgets, establishing appropriate indirect cost rates, approving subcontracts and major capital expenditures, resolving audits of both systems and costs, and monitoring costs.

NSF's Office of Inspector General (OIG) is responsible for audit and oversight of NSF programs and operations, including programs to support specialized research facilities. Research facilities at universities and commercial and nonprofit organizations are regularly audited by OIG. OIG also reviews and evaluates internal financial, administrative, and programmatic aspects of NSF activities, including activities related to facilities programs.

Conclusion

The National Science Foundation will continue to plan for new specialized research facilities based primarily on scientific opportunities and technical considerations. These plans will be integrated into the Foundation's overall priorities, and will continue to be considered in the context of other Foundation activities and obligations. The rising costs of these facilities will require increased attention to innovative financing arrangements, cost sharing, and international collaborations.

APPENDIX I

A REPORT TO THE
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
U. S. HOUSE OF REPRESENTATIVES

FEBRUARY 28, 1990

PLANNING AND PRIORITY-SETTING IN THE NATIONAL SCIENCE FOUNDATION

Overview

This report describes the process by which NSF develops program plans, sets priorities among them, and seeks approval from the Administration and the Congress to carry them out. The process is continuous, open, and decentralized. It offers many points of input for the scientific, engineering and education communities which are NSF's major clientele, and for the public at large. The decision cycle is keyed to the Federal budget and appropriation calendar. This report outlines each major phase of the process: the chronology and key events, major participants, and the nature of the interaction at each step. Finally, an appendix lists some of the reports, conferences, and workshops that have contributed to the priority-setting process in recent years.

Chronology

The table on the following page summarizes the principal phases of the planning process which leads to a particular year's program plan and budget proposal. This cycle is two full years in duration. In January of 1990, NSF initiated the formal planning process which will eventuate in the FY 1992 budget and a five-year plan for the period 1992-96. At any given time, we are engaged in three different planning cycles:

-implementation of current year programs;
-justification of plans and budgets for the coming year; and
-planning for the new budget year.

For clarity, these are treated sequentially in this report. In reality, they occur simultaneously; there are feedback loops throughout the process, and near-term events often result in changes in long range plans.

NSF PLANNING AND BUDGET PROCESS

TIME	ACTIVITY	PARTICIPANTS
Continuous	Identifying scientific opportunities, needs	NSF program staff advisory committees research community
January-June current year	Planning for next (CY +2) budget cycle	NSF program staff advisory committees NSF management National Science Board

Key event--June National Science Board meeting--Board reviews long range plan and provides budget guidance to staff

June-August	Preparing the budget request to the Administration	NSF management National Science Board

Key events--National Science Board approves budget at August meeting for submission to Office of Management and Budget on September 1

September-December	Deciding on the President's budget request	NSF management OSTP & interagency OMB

Key event--The President submits his budget to the Congress in early January

January-June (CY +1)	Justifying the budget to the Congress	NSF management Congressional committees Interest groups

Key events--Appropriations, authorization and oversight hearings

July-September	Enacting appropriations and authorizations	Congress President

Key events--passage and approval of legislation

October	Implementing the budget & program plan	NSF program staff Scientific community NSF management

Continuous Planning

Planning is a continuous activity at NSF. The identification of scientific opportunities and development of program concepts is largely a "bottom-up" process, with the scientific community as the major source of information and ideas. This process follows no particular calendar: it can be driven by a scientific breakthrough, the availability of a new technology, national or international concerns, or simply the existence of a new idea.

Some of the major mechanisms for this ongoing dialogue between NSF management and the science and engineering research and education communities include the following:

--Advisory Committees--NSF has 71 chartered advisory committees comprised of nearly 900 scientists, engineers and educators. These committees are a major source of scientific and programmatic advice. Most represent a particular discipline or field of science; a smaller number reflect the interdisciplinary nature of the programs they advise. Membership on advisory committees is carefully balanced with respect to disciplinary, institutional, geographic and demographic representation; 1/3 of the membership rotates annually, so there is a constant influx of new people and ideas.

The full committees generally meet twice a year; task groups and sub-panels meet more frequently. Their meetings are attended by interested NSF staff, members of the community at large, and the science press. The Director and other senior staff routinely meet with Advisory Committees for face-to-face discussions, and the minutes of the meetings receive wide distribution and attention. All are actively involved in the development of program plans and priorities, as well as assessments of current program activities.

--National Science Board (NSB). The 25 members of the NSB are appointed by the President with the advice and consent of the Senate. The Board's membership represents the range of the scientific and technical disciplines supported by NSF; in addition, the Board frequently invites other individuals to take part in its deliberations.

The NSB bears statutory responsibility for establishing NSF policy and approving NSF programs. Its standing committees continuously examine current and proposed NSF activities and probe policy issues; special task forces, committees, and commissions are established to deal with matters of particular complexity or urgency.

In recent years, NSB reports have given major impetus to agency programs in such diverse areas as undergraduate education, polar research, plant science, advanced scientific computing, and biodiversity. For some years, the NSB has voiced serious concern about the state of science and engineering education and the attraction of enough young people to scientific and technical professions. It was the driving force behind NSF's new programs in undergraduate education, has supported new programs to attract underrepresented groups--women, minorities, the disabled--into science and engineering careers, and has championed the rebuilding of NSF precollege education activities.

--Professional Societies: The interest groups and professional societies and associations which represent external communities often take part in advisory committee and NSB meetings, as outlined above, as well as workshops, symposia, and other occasions which are the settings for scientific communication. There are also well-developed electronic "bulletin boards" and other informal communications networks in which NSF staff participate fully.

NSF senior management meets with many groups which provide advice and information on the interests of parts of the research and education communities. The Director has met with groups of college and university presidents, deans, industrial and Federal laboratory directors, heads of private foundations, and the presidents and executive directors of professional groups and associations. The Foundation periodically holds open meetings with these groups regarding budget and program plans, and the Chair of the NSB and the Director hold regular informal briefings for the science press and other spokesmen for special interest groups.

--National Research Council (NRC): The Foundation, frequently asks the NRC or one of its constituent Academies to provide advice on programmatic, scientific, and policy issues. These reports often play a key role in program development and priority decisions. In recent years, the Engineering Research Centers and Science and Technology Centers programs have been developed around NRC reports; and initiatives in materials research, mathematics, astronomy, chemistry, and other areas have been strongly influenced by Academy advice.

--Visiting Scientists, Engineers, and Educators (VSEE)-- About 1/3 of the scientific and technical staff of NSF is comprised of VSEE's on temporary assignment, normally of 1-3 years' duration. They are typically leaders in the professional and scholarly groups which represent their fields. They bring direct knowledge of forefront research, and put it to work on a daily basis in the management of their own programs and through formal and informal communication with other NSF staff.

--Quarterly Reviews: The Director and senior staff meet with each directorate four times each year for an extensive review of program activities. Members of advisory committees and other individuals from the external community are frequently invited to take part. These reviews address the full range of scientific, budgetary, and management topics, and often provide the first airing of concepts which later emerge as scientific initiatives or new programs. The spring round of quarterly reviews is explicitly dedicated to long range planning.

--Interdirectorate Task Forces: NSF management makes extensive use of interdirectorate working groups and task forces to assess new program ideas and develop implementation strategies. Such groups have been the source of such recent NSF research initiatives as biotechnology, chemistry of life processes, and global geosciences. Internal task forces also developed the Alliances for Minority Participation and Faculty Awards for Women programs that are introduced in the FY 1991 budget request.

The Formal Planning Cycle

Because of the extensive ongoing planning activities described in the preceding section, the explicit planning exercise is largely a matter of selecting, from a wealth of interesting and compelling scientific and programmatic ideas, those which are to be emphasized in the particular program plan and budget. These choices are shaped by many considerations; to name a few:

--scientific readiness
--technical feasibility
--response to national needs
--affordability
--balance with existing programs

--The Period of Intra-NSF Planning. This narrowing process generally begins in January or February, at a retreat attended by the Director, the Assistant Directors, and other senior staff. NSF uses a five-year planning horizon: the group examines the existing 5-year plan, assesses whether it still provides an adequate framework for the new planning period, and identifies a list of candidate issues and opportunities for the upcoming budget cycle. These typically include both specific programmatic topics such as supercomputing or environmental research, and broader resource or policy issues such as adequacy of instrumentation or problems in the educational pipeline.

Throughout the spring, this candidate list is further explored. Each directorate undertakes its own internal priority-setting reviews, typically involving advisory committees, and presents the results to the Director and senior staff in the spring round of Quarterly Reviews. At these reviews, the status of each major field of science is examined--critical research opportunities; human resource trends; employment in the field; NSF and other agency funding trends; institutional infrastructure; instrumentation and facilities; and international implications.

Cross-directorate task forces and working groups are established to address topics which cross traditional disciplinary boundaries. In May, all Advisory Committee chairs are brought together for meetings with senior NSF management--the Director, Assistant Directors, and the National Science Board--for further discussions of major issues and opportunities that have emerged from the planning process.

This activity culminates at the June meeting of the NSB, at which time the staff presents recommendations and findings. The Board indicates which of the activities or issues it finds most compelling, and provides general guidance to the staff as to the size and scope of the budget proposal that should be prepared. In recent years, the NSB has assigned high priority to education and human resource development. This priority has been reflected in the selection of new programs, in differential rates of budget growth for activities which directly address this need, and in redirection within base programs (e.g., greater emphasis on support for graduate students and research initiation grants in all fields). The second area of persistent NSB attention has been the role of research and education in economic competitiveness. This has been manifested by attention to knowledge transfer in all fields and programs, closer ties to the private sector, and again, in the emphasis on education and human resources issues.

--Preparing the Budget Request. From mid-June to August, the staff prepares the budget request; the NSB reviews and approves the request at its August meeting, prior to the September 1 submission to the Office of Management and Budget (OMB).

It is in developing the OMB request that the allocation of resources to particular directorates and divisions first emerges. Until this point, all agency-level planning has focused on cross-cutting thematic or functional considerations. The decision, for example, to initiate programs in undergraduate education involved a number of subsidiary resource allocation decisions among directorates and fields of science. Even "pure" research augmentation decisions fall unevenly: superconductivity research involves chemists, physicists, materials scientists, and engineers; global change research engages the geosciences, environmental biology, social sciences, and polar programs.

The only case in recent years in which explicit priority has been given to a particular discipline is mathematics. Widespread concern had developed about the lack of faculty and practitioners in mathematics, culminating in an influential NRC report which was endorsed by the leadership of virtually all scientific and engineering disciplines. As a result of these concerns, the Mathematics Division of NSF received substantial increases for several years in succession to support greatly increased numbers of graduate students and postdoctoral scholars.

From September through December, NSF is engaged in Administration-wide planning for the President's budget. During the past several years, research and education issues have been among the central concerns of the Administration. The original decision to seek a rapid doubling of the NSF budget, and its reassertion by the current Administration, emerged from top-level policy deliberations involving OMB, the Office of Science and Technology Policy (OSTP), the President's Science Advisor, and the Cabinet.

As part of this focus on science and technology issues, the interagency planning process has emerged as an important source of input to budget priorities. The Federal Coordinating Council on Science and Engineering Technology (FCCSET) and its constituent committees played a major role in the development of the US Global Change Research Program, a billion-dollar Presidential initiative in FY 1991, and in interagency efforts in other areas such as high-performance computing and superconductivity. Cabinet Councils and task groups have played a similar role in such areas as economic competitiveness and education. Decisions taken at this level are cycled back to agencies for incorporation into their final budgets and program plans.

By the time the President's budget is released, the NSF component has been shaped by both scientific and policy imperatives. The early part of the planning process is entirely open and largely science-driven; it produces far more worthwhile initiatives than can be supported. Resource limitations require that choices be made. Those choices are shaped by the advice and information generated by the research community at large, but are ultimately made by the staff and senior management of the Foundation, the NSB, and the Administration.

Congressional Review and Action

This report will not dwell on the mechanics of this part of the process, since they are well known to the Committee. We will note, however, some of the significant ways in which events in this phase feed back into plans for future activities.

Congressional response to the planned doubling of the NSF budget has been generally favorable. This has been manifested by the passage of the five-year authorization endorsing the rapid doubling of the NSF budget (P.L. 100-570), most of the budget legislation enacted during this period, and generally supportive hearings and reports in the appropriations committees of both houses. But larger issues of resource constraints, as well as policy differences involving other parts of the appropriations omnibus in which NSF is housed, have resulted in substantially smaller appropriations than requested, for Research and Related Activities (R&RA), NSF's largest Appropriation Account. The original doubling plan called for R&RA to reach $2.15 Billion in FY 1990: the actual FY 1990 Current Plan is $430 Million short of that figure.

In part, the Congress has specified the distribution of the reduced R&RA appropriation in the form of across-the-board or formula adjustments, or floors or ceilings on certain programs or activities. To the extent that NSF has retained the authority to apportion reductions, our actions have been governed by the same priorities which formed the original plans. These changes are manifested first in the "current plan" which adjusts each year's programs to the funding provided, and secondly, by amendments to long range plans to take account of intervening changes.

The highest priority in NSF's doubling plan was assigned to human resource investment. That area has accordingly enjoyed a higher rate of growth than other activities. From 1986-1990, investment in undergraduate education increased from $40 to $100 Million; and programs to enhance the representation of women, minorities and other underrepresented groups in science and engineering more than doubled. We moved ahead with increased funding for graduate students and postdoctoral scholars in mathematics and other fields, and increased the share of funding available to initiate the research careers of young investigators through the Presidential Young Investigators (PYI) and a number of disciplinary research initiation programs. Engineering and Science and Technology Research Centers also have significant human resource dimensions, involving undergraduate students, high school teachers and students, as well as graduate students in forefront research.

The cost of protecting these human resource activities has been persistent under-investment in secondary priorities, such as research equipment and facilities. Over time, this has resulted in growing pressure on operations of existing facilities and deferral of much-needed acquisitions. The Fiscal Year 1991 request includes several initiatives which address these increasingly urgent requirements.

The NSF doubling plan calls for balanced growth across all research fields, but with particular attention to areas which contribute to economic competitiveness. Actual appropriations have not permitted the rates of growth desired, but the relative priorities have remained intact: biotechnology, superconductivity, manufacturing, advanced computing and networking, and materials have been among the beneficiaries.

NSF's research plans have given special attention to global environmental research. We have proceeded with new or expanded efforts in polar research, biodiversity, climate change and related areas. The 1991 Presidential initiative in Global Change Research draws heavily from this long-term NSF effort, and accelerates our plans in this area.

Individual investigators receive the majority of NSF research support, but the increasingly interdisciplinary nature of much forefront research has made it imperative to provide support as well for more coordinated efforts of research groups and centers. Based on the recommendations of advisory committees and other representations from the research community itself, in the past few years NSF has initiated or expanded support to research groups in mathematics, materials, earth science, and computer science and engineering. Reports from the NRC and its constituent Academies provided impetus for the establishment of research centers, recommendations which have been manifested in NSF plans and budget requests. Because of the reduced appropriations available in R&RA, however, we have slowed progress toward these objectives in order to maintain a balanced research support portfolio. But the fundamental reasons for establishing these programs remain unchanged, and we will continue to move ahead responsibly, but purposefully, in this area.

Conclusion:

Planning is a continuous process at NSF. The explicit planning for a particular fiscal year's program plan and budget proposal spans two full years and provides many opportunities for external advice and comment. The early part of the planning process is largely science-driven. It is conducted openly, with the participation of the research and education communities and other interested groups. Content of this phase of planning is shaped primarily by advice and information from the external community: it is not constrained by resource limitations or guided by policy directives. This is a very fruitful period which results in identification of many program opportunities and much useful guidance about priorities within programmatic fields and scientific disciplines.

The second part of the process occurs within the Executive Branch. It is at this point that resource limitations and policy considerations are overlaid on the many possible initiatives which have been produced by the earlier planning.

Priorities must be assigned and choices made. These decisions are shaped by many considerations:

- --scientific readiness;
- --technical feasibility;
- --response to national needs;
- --affordability; and
- --balance with other programs of NSF and other agencies.

These choices are shaped to a considerable extent by external advice and information, but in the end, they must be made by NSF staff and management, the National Science Board, and ultimately, by the Administration as a whole.

The third part of the process involves Congressional review and approval of program plans and budget proposals.

Congressional views and priorities are reflected in authorization and appropriations legislation, but also through hearings, testimony, General Accounting Office (GAO) and Office of Technology Assessment (OTA) reports, committee reports, and other interactions. The most direct and immediate impact of this review is on near-term program implementation, but Congressional guidance also feeds back into the planning cycle. Significant changes to the level or distribution of resources in the base alter planning assumptions; different perspectives on agency programs and priorities may suggest changes in long range plans; and signals about future funding and policy environments also must be taken into account.

-OSTP. The Federal High Performance Computing Program, 1989. Implementation plan to guide agency programs in supercomputing and networking. Influencing program planning.

-NRC. The National Challenge in Computer Science and Technology, 1988. Outlined and confirmed role of computing in national economic competitiveness, and stressed impact of basic research and human resources in CS/CE; assisted focus on economic competitiveness in CISE budget request.

-NRC. The Impact of Supercomputing Capabilities on US Materials Science and Technology, 1988. Stressed impact of supercomputing access and research on materials science, need for highest capability machines; focused attention on capability rather than capacity as criterion in centers renewal.

-NAS. Scaling Up: Research Agenda for Software Engineering, 1989. Review of research practices and topics. Suggestions for research progams in critical areas. Influencing program planning.

-NAS. Keeping the U.S. Computer Industry Competitive: Defining the Agenda, 1990. Strategic view of research needed in computer hardware, software, and service/systems integration. Influencing program planning.

-ENGINEERING

-NRC. Directions in Engineering Research: An Assessment of Opportunities and Needs, 1987. On-going influence on priority setting within engineering programs.

-NSF. Report of the 1988 NSF Workshop on Undergraduate Engineering Education, 1988. This report influenced Engineering (and SEE) to emphasize undergraduate curriculum development in engineering within ENG's total undergraduate and human resources effort.

-NAS. Confronting Natural Disasters: An International Decade for Natural Hazard Reduction. The Earthquake Hazard Mitigation and Natural and Man Made Hazard Mitigation Programs are using this report to help plan our participation in the Decade.

-Interim Report of the Task Force on Women, Minorities, and the Handicapped in Science and Engineering. Changing America: The New Face of Science and Engineering, 1988. Influential in providing impetus for engineering women/minority efforts.

-NAS. Guidelines for Engineering Research Centers, 1983. Influenced level of funding, targets for long-term goals, and how to achieve goals.

-NAE. Assessment of the National Science Foundation's Engineering Research Centers Program, 1989. Report requested by NSF to consider program's impact and future directions. Impacted NSF's decision in FY 1991 to not fund any new centers, but rather to increase base funding of existing centers.

-Imperatives in Undergraduate Engineering Education, 1989. Recommended expanding undergraduate curriculum development by developing a number of consortia of educational institutions. Led to the Engineering Education Coalitions program.

-GEOSCIENCES

Global Change

There have been a number of reports relating to various aspects of global change. Examples include:

-Toward an International Geosphere-Biosphere Program: A Study of Global Change, 1983.

-NAS/NRC. Global Change in the Geosphere-Biosphere: Initial Priorities for an IGBP, 1986.

-Global Ocean Flux Study: Influence Planning on GOFS, 1984. Planning document for one element of the Global Change Research Program.

These and other reports have contributed to:

-Committee on Earth Sciences, FCCSET. Our Changing Planet. A U.S. Strategy for Global Change Research, 1989 and 1990. This report articulates global change research objectives and an implementation plan for federal agencies. The plan accompanied the President's FY 1991 budget and includes $103 M for NSF, an 87 percent increase over FY 1990.

Atmospheric Sciences

-NAS/NRC. Low-Altitude Wind Shear and its Hazard to Aviation, 1983. Used by the National Center for Atmospheric Research (NCAR) to set research priorities.

-Opportunities for Research at the Atmosphere/Biosphere Interface, 1985. Prepared by the University Corporation for Atmospheric Research (UCAR) for planning in both the Atmospheric and the Ocean Sciences.

APPENDIX

Below is a list of recent reports that have influenced the way the National Science Foundation has set funding priorities:

-BIOLOGICAL, BEHAVIORAL AND SOCIAL SCIENCES

-OTA. Commercial Biotechnology: An International Analysis, 1984. Provided general background for planning.

-International Trade Administration. High Technology Industries: Profiles and Outlooks. Biotechnology, 1984. Provided general background for planning.

-The Needs of Biological Field Stations, 1985. Led to formation of special competition for equipment and facilities at biological field stations, which began in FY 1986.

-U.S. Strategy on the Conservation of Biological Diversity, 1985. An interagency task force, Report to Congress. Provided specific background on issues, especially the needs in developing countries for scientific infrastructure and education, manifested within the FY 1990 BBS budget request.

-NRC. State of the Art Reviews. Cell Biology: Basic Research and Applications, 1986. A general review that was not specifically useful.

-OTA. Technologies to Maintain Biological Diversity, 1987. A general background document that overall was an extremely well-done technical overview. It influenced the plans for the biodiversity initiative in the FY 1990 BBS budget request.

-Report of the Ann Arbor Workshop on an International Social Science Research Program on Global Change, 1987. Had direct impact on CES objectives and FY 1991 NSF budget request as well as providing background justifying special solicitation in Social and Economic Science on "human dimensions of global change."

-OTA. Technologies to Maintain Biological Diversity, 1987. This report provided important background to an NSB task force on global diversity as well as a new budget initiative on biodiversity in FY 1990 request.

-Environmental Biotechnology: Reducing Risks for Environmental Chemicals through Biotechnology, 1988. This conference helped focus on microbial ecology and the continuing emphasis on biotechnology that began in 1984.

-NAS. Biodiversity, 1988. Useful review papers cited extensively in NSB Biodiversity report.

-NRC. Use of Laboratory Animals in Biomedical and Behavioral Research, 1988. Useful report to the community about several types of concerns about use of laboratory animals. There has not been any impact on budgets; that wasn't the purpose of the study.

-NRC. Opportunities in Biology, 1989. General illustrative material; has not, and likely will not, be useful in budget planning effort because it is too general.

-NSF. Profiles--Biological Sciences: Human Resources and Funding, 1989. Good resource for human resources. Just out, but draft data were useful in overall planning for education and human resources efforts.

-Second Conference on Conservation Biology, 1989. A widely cited book on conservation biology which was used extensively by BBS in developing initiatives in conservation biology and biodiversity.

-National Science Board. Loss of Biological Diversity: A Global Crisis Requiring International Solutions, 1989. NSB-89-171. Action-oriented document impacting directly the FY 1990 and 1991 budget requests, and probably FY 1992 and continuing for at least a few more budget cycles.

-Biological Collection Resources for the 1990's, 1989 and 1990. Influenced NSB Task Force on Biological Diversity and helped BBS design programs for support of databases for natural history collections in FY 1990 and 1991 budgets.

-COMPUTER AND INFORMATION SCIENCE AND ENGINEERING

-Lax, Peter. Report on the Panel on Large Scale Computing in Science and Engineering (DOD and NSF), 1982. Established goals for NSF ASC activity: supercomputing access, networking, software/algorithm research, training, balanced computing environment.

-FCCSET/OSTP. A National Strategy for High Performance Computing, 1987. Brought together interagency cooperative activity on high performance computing research and national networking. Led to NSF national network leadership and program focus within CISE. An implementation plan, with a FY '90 interagency budget initiative, is currently being formed. This is modeled after the Global Change initiative.

-NRC. Toward A National Research Network, 1988. Confirmed soundness of FCCSET views of needs and scope for national research network.

-NSF/UCAR. The Atmospheric Sciences: A Vision for 1989 - 1994, 1987. Long range plan for atmospheric sciences.

Arctic Research

-NAS/NRC. National Issues and Research Priorities in the Arctic, 1985. Influenced planning for NSF's Arctic Research Program.

-NAS/NRC. Priorities in Arctic Marine Science, 1988.

-Arctic Interactions: Recommendations for an Arctic Component in the International Geosphere-Biosphere Programme, 1988. Prepared by the University for Atmospheric Research (UCAR).

-NAS/NRC. Arctic Social Science. An Agenda for Action, 1989. Provides guidance for NSF's Arctic Social Sciences Program, a newly established program with an FY 1991 request of $1.0 million.

-Arctic Oceans Research: Strategy for an FY 1991 U.S. Program, 1990. A report accompanying the President's FY 1991 Budget which outlines goals, strategies, and budgets for research in the unique arctic environment. It includes $9.40 million for NSF in FY 1991, a 47 percent increase over FY 1990.

Earth Sciences

-NAS/NRC. Priorities for a National Continental Scientific Drilling Program, 1984. Useful in providing guidance for planning the Continental Lithosphere Program.

-NAS/NRC. Priorities for a National Continental Scientific Drilling Program, 1985. Used in the long-range planning for the Continental Lithosphere Program.

-NSF, DOE, USGS Sponsored Workshop. The Future of Accelerator Mass Spectrometry in the USA, 1985.

-Advisory Committee for Earth Sciences, A Unified Theory of Planet Earth: A Strategic Overview and Long Range Plan for the Division of Earth Sciences, 1988.

Ocean Sciences

-Oceanography from Space: A Research Strategy for the Decade 1985-1985: Part 1: Executive Summary (July 1984) and Part 2: Proposed Measurements and Mission, 1985.

-A Unified Plan for Ocean Science: A Long-Range Plan for the Division of Ocean Sciences of the National Science Foundation, 1987. Prepared by the Advisory Committee for OCE.

-MATHEMATICAL AND PHYSICAL SCIENCES

Mathematics

-NAS/NRC. Reviewing U.S. Mathematics: Critical Resource for the Future, 1984. The David Report. Significant effect on funding in mathematical sciences. By FY 1990, Division of Mathematical Sciences increased over 30% in five years. Update to the David Report in now in process -- early data and ideas have already influenced planning.

-Rheinboldt, Werner C. Report on the Panel on Future Directions in Computational Mathematics, Algorithms, and Scientific Software, 1985. The Rheinboldt Report (supported by NSF grant). Played significant role in Foundation's development of an initiative in computational science and engineering and creation of Computational Math program.

-Institute for Mathematical Statistics. Report on Cross-Disciplinary Research in the Statistical Sciences, 1988. Affected planning in the area of applied statistics and probability.

-NAS/NRC. Mathematical Sciences in the Year 2000. Study now underway. Early data and draft documents have influenced planning in undergraduate areas.

Astronomy

-NAS/NRC. Astronomy and Astrophysics for the 1980's, 1982. Field Committee Report. In response to this report, the Foundation increased funding for astronomy in FY 1984 and undertook the construction of the VLBA and the installation of the Caltech submillimeter telescope.

Field report also recommended design studies for 16-m class optical/infrared telescope. Light-weight mirror work at Arizona responds to that recommendation. Plans for 8-m telescopes keep us in competitive position in optical astronomy, and represent an intermediate response to 16-m recommendation.

-New "decade study" underway -- Astronomy and Astrophysics for the 1990's -- expected mid 1991. Report will examine what is now the appropriate step beyond 8-m.

Astronomy Advisory Committee Reports:

- Report of Subcommittee on NSF Radio Astronomy Facilities, 1988. The Langenberg Report. Evaluated scientific priorities of NSF radio astronomy observatories.

- Report of the Subcommittee on Long Range Plans for Radio Astronomy, 1989. Established priority for NAIC/Arecibio upgrade (included in FY 1991 Budget Request).

- Report of Subcommittee on Ground-Based Optical/Infrared Astronomy, 1989. Highlighted priority for 8-m telescopes (included in FY 1991 Budget request).

Physics

-NAS/NRC. Physics Through the 1990s, 1986. The Brinkman Report. Influenced funding in atomic theory and in atomic, molecular and optical physics. (Report did not set priorities.)

-NSF/DOE. Nuclei, Nucleons and Quarks: Nuclear Science in the 1990's, 1989. Long range plan by NSF/DOE Nuclear Science Advisory Committee (NSAC). Most recent five year plan, provides advice to NSF and DOE for the next decade.

-DOE. Report of High Energy Physics Advisory Panel (HEPAP) Subpanel on Future Modes of Experimental Research in High Energy Physics, 1988. Examined new facilities and changing modes of doing experiments in high energy physics (HEP). Recommended continued system of dual support for HEP by DOE and NSF. NSF/PHY increase for instrumentation/detectors in FY 1990 Budget Request responded to report, but FY 1990 Current Plan not able to provide increased support.

Chemistry

-NAS/NRC. Opportunities in Chemistry: A Report to the Committee to Survey Opportunities in the Chemical Sciences, 1985. The Pimentel Report. Led to a reorganization of NSF's Chemistry Division and stimulated such funding initiatives as Chemistry of Life Processes, and Materials Chemistry.

-NSF. Report on Workshop on Physical Chemistry, 1987. Influenced funding patterns within the physical chemistry programs of the CHE Division.
(For other CHE-related, see also reports under Materials Research)

Materials Research

-NRC(NMAB-451). The Impact of Supercomputing Capabilities on U.S. Materials Science and Technology, 1988. Used to plan computational science/engineering expansion in materials science research in early 1990's.

-Seitz-Richardson. Report of NSF Panel on Large Magnetic Fields, 1988. Findings and recommendations in this report provided basis for FY 1990 budget request for new National High Magnetic Field Laboratory.

-NAS/NRC. Materials Science and Engineering for the 1990s, 1989. Influenced planning for FY 1991 -- for example, emphasis on materials synthesis and processing (in DMR, CHE, ENG). Will have continued influence in the 1990s.

[Precursor to MS&E Report above, NAE/NAS report Advancing Materials Research, 1987, had influence in broadening the Materials Chemistry initiative into Materials Chemistry and Chemical Processing.]

-SCIENCE AND TECHNOLOGY CENTERS

-NAS. Science and Technology Centers: Principles and Guidelines, 1987. This panel recommended that NSF treat the STC program as a single competition across all fields of science and technology.

-SCIENTIFIC, TECHNOLOGICAL, AND INTERNATIONAL AFFAIRS

-NAS. Surveying the Nation's Scientists and Engineers, 1989. NSF commissioned study of the Scientific and Technical Personnel Data System (STPDS) which Science Resources Studies operates. NSF response being in FY 1990 and FY 1991 budget request plans for major upgrade.

-NSF. College and University Innovation Research (CUIR), 1989. Report generated by NSF in response to NSF Authorization Act of 1989. Pilot program proposed in FY 1991 budget request.

-SCIENCE AND ENGINEERING EDUCATION

-National Science Board. Educating Americans for the 21st Century, 1983. Report of the NSB Commission on Precollege Education in Mathematics, Science and Technology. Developed framework under which precollege programs have been instituted and expanded.

-National Science Board. Undergraduate Science, Mathematics and Engineering Education, 1986. (The Neal Report; NSB 86-10). Developed NSF leadership role recognizing importance of undergraduate research and education. Recommendations were made in programmatic areas. NSF implementation began during 1987, and exceeds $130 million in FY 1991 request.

-SRI International. Opportunities for Strategic Investment in K-12 Science Education, 1987. Helped NSF/SEE examine and devlop a long range planning strategy for science and mathematics education programs.

-Triangle Coalition for Science and Technology Education. A Plan for Action, 1989. Provides policymakers with a specific series of actions to address problems in science and technology education.

-Carnegie Council on Adolescent Development. Turning Points - Preparing American Youth for the 21st Century, 1989. Report recommends transforming middle grade schools. Helps to guide further development of programs for middle school mathematics and science materials development and teacher enhancement.

-American Association of State Colleges and Universities. Formula for Reform - The Role of the Comprehensive University in Undergraduate Science and Engineering Education, 1989. Report offers policy recommendations to address problems in undergraduate education. Being reviewed by NSF for policy and program input.

-National Center for Improving Science Education. Assessment of Elementary School Science Education, 1989. Report helps to guide planning for teacher development and enhancement and materials development at the elementary school level.

-Government-University-Industry Research Roundtable. Science and Technology in the Academic Enterprise: Status, Trends, and Issues, 1989. Analysis of the status of science and technology research in academic settings and identification of issues (including education) central to its future.

-American Association for the Advancement of Science (AAAS). Science for All Americans (Project 2061), 1989. Report of the first of three phases of a decade-long K-12 science curriculum reform project.

-National Center for Improving Science Education. Science and Technology Education for the Elementary Years: Frameworks for Curriculum and Instruction, 1989. A policy statement for curriculum and instruction in elementary schools. Helps to guide development of programs for elementary science and mathemeatics education.

-NSF. Report on the National Science Foundation Disciplinary Workshops on Undergraduate Education, 1989. Established framework for course and curriculum improvement and devlopment programs, notably at the introductory levels.

-UNITED STATES ANTARCTIC PROGRAM

-NAS/NRC. Research Emphases for the U.S. Antarctic Program, 1983.

-NAS/NRC. U.S. Research in Antarctica in 2000 A.D. and Beyond A Preliminary Assessment, 1986.

-National Science Board. The Role of the National Science Foundation in Polar Regions, 1987. Report of the NSB Committee on the NSF Role in Polar Programs. Recommendations in this report led to an initiative to double the core support for polar research over three years; contributed to the establishment of the Safety, Environment, and Health Initiative; and led to the establishment of a program in Arctic Social Sciences.

-Safety in Antarctica, 1988. Recommendations in this report led to the major, multi-year Safety, Environment, and Health initiative proposed in the FY 1990 budget ($8.3 million in FY 1990; $23.0 million in FY 1991). The report was commissioned by NSF; it was carried out by a distinguished committee of external experts.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
DIRECTOR

November 16, 1990

Honorable Robert A. Roe, Chairman
House of Representatives
Science, Space, and Technology Committee
2321 Rayburn House Office Building
Washington, DC 20515-6301

Dear Mr. Chairman:

Enclosed herewith is a report to the Committee entitled "The Infrastructure of Undergraduate Education." This report was prepared by the Division of Undergraduate Science, Engineering, and Mathematics Education in the Foundation's Directorate for Education and Human Resources. It is submitted in response to the Committee's request embodied in House Report 101-309, "Oversight of National Science Foundation FY1990 Programs."

The Committee requested that " . . . NSF explore possible actions which the Foundation could take that would result in greater attention by faculty to undergraduate instruction and that would reward outstanding teachers." After a brief survey of "The Current Scene," the report sets forth "The NSF Response in Terms of Programs" to meet the additional needs of all schools, two-year colleges, predominantly undergraduate institutions, and doctoral universities.

We believe that implementation of the programs suggested by this report would greatly strengthen undergraduate science, mathematics, and engineering education in the United States.

We look forward to discussing this report with you.

Sincerely,

Frederick M. Bernthal
Acting Director

Enclosure: Report

cc: Honorable Robert S. Walker

NATIONAL SCIENCE FOUNDATION
1800 G STREET, N.W.
WASHINGTON, D.C. 20550

THE INFRASTRUCTURE OF UNDERGRADUATE EDUCATION

A REPORT TO THE U.S. HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY CONCERNING ACTIONS THAT NSF COULD TAKE TO IMPROVE THE QUALITY OF UNDERGRADUATE INSTRUCTION

ABSTRACT: *In order to achieve a new balance of teaching and research that would strengthen undergraduate instruction, NSF should foster a national community of scholars by engaging large numbers of instructors of undergraduates in improvement activities and connecting them in a network of communication.*

The National Science Foundation is pleased to respond to the following request of the Committee:

> Young faculty members are well aware that proficiency in research leads to promotion and tenure and that teaching skill contributes little to their professional advancement. Since the quality of undergraduate instruction is a critical factor in cultivating student interest in science and engineering and in maintaining the human resource pipeline, the Committee requests that NSF explore possible actions which the Foundation could take that would result in greater attention by faculty to undergraduate instruction and that would reward outstanding teachers.

The culture of the United States is based increasingly on science and engineering. It is alarming that this core of our culture is failing to generate the scientists and engineers needed to carry it on and lies beyond the knowledge of most citizens. No activity is more strongly connected to these problems than undergraduate instruction.

The NSF considers the task before the Nation to be revitalizing the instruction of undergraduates rather than reorienting the academic culture from research to teaching. The latter describes only part of the problem because the settings for educating undergraduates are highly diverse. What NSF terms "predominantly undergraduate institutions" account for about 60% of U.S. science baccalaureates. The 104 institutions classified by Carnegie as research universities I and II account for 36% of science baccalaureates, doctorate and comprehensive universities for 49%, and liberal arts colleges for 15%. Moreover, about a third of the science enrollment in the first two years of college is in two-year colleges. These settings require different remedies. To strengthen instruction, some faculty should do more rather than less scholarship, some should pursue different scholarship, and some need to engage teaching in new ways.

Regarding "possible actions which the Foundation could take..," NSF acts by providing grants that involve faculty in specific activities. To achieve a new balance, grant programs must rechannel faculty activity. The overall plan should recognize the needs of faculty from at least three categories of institutions: doctoral institutions, predominantly undergraduate institutions, and two-year colleges. Teaching is already emphasized at the schools in the latter two categories; most faculty at these schools need support for scholarly activities in order to improve their instruction. Many faculty at doctoral universities have an abundance of scholarship; they need support to reembrace teaching and to foster scholarship of faculty at other schools. NSF believes strongly that research and teaching are mutually supportive. For research-oriented faculty at any institution, therefore, NSF wishes to sustain their interest in research while expanding their interest in teaching. This means that NSF must make instructional innovation and improvement a viable arena for professional activity.

The long-term solution requires more than making a few large, widely publicized awards to already exemplary teacher/scholars. The Nation must create a robust culture in the science and engineering education communities. We must find ways to engage the minds and energies of thousands of faculty in all kinds of institutions in a huge network of contacts, bright ideas, and activities. This argues for many programs that make thousands of grants to individuals for a variety of activities, an approach in accordance with the "thousand points of light" advocated by President Bush. The individual lights, however, need a framework to obtain coherence and staying power, and we must, therefore, consider substantial direct investments in inter-institutional infrastructure.

THE CURRENT SCENE

The perception is widespread in the public and in academia that undergraduate teaching has fallen on hard times. The bestseller, Profscam, by Charles J. Sykes (1988),, is an example. This book claims that the universities and colleges and their faculties have abandoned teaching. Unfortunately, this viewpoint enjoys a large audience. Moreover, opinion pieces on poor undergraduate teaching are embarrassingly easy to find. For example, an editorial in the Washington Post on July 28, 1990, supported a plan of Yale University to decrease graduate teaching assistantships in order to put more teaching duties on senior faculty. The President of Stanford University, Donald Kennedy, put the matter clearly in a speech in April of 1990:

> Teaching and research are both important, but the relative weight has shifted over time, as the relatively new term "research university" suggests. It is time for us to reaffirm that education - that is, teaching in all its forms - is the primary task and that our society will judge us in the long run on how well we do it.

The NSF believes that the general quality of undergraduate teaching is low and that this contributes importantly to the crisis in science and engineering education. The following findings support this view:

- 65% of high school seniors and 54% of college freshmen with strong interest in science or engineering careers do not achieve baccalaureate degrees in those fields (R. C. Atkinson, Science, 248, 425 (1990));
- one out of 15 U.S. adults and one out of five U.S. college graduates is literate in science (J. D. Miller, Daedalus, 112, 29 (1983));
- primary and secondary school teachers consider science to be the area in which they are least prepared to teach (I. R. Weiss, 1977 Natl. Survey of Sci., Math., and Soc. St. Educ., Wash. DC: U.S. Govt. Pr. Off., 1978);
- about half of U.S. Ph.D. degrees in engineering and several quantitative sciences are now awarded to foreign nationals (Science and Eng. Indicators-1989, National Science Board).

Following the report of the National Science Board (NSB) on Undergraduate Science, Mathematics, and Engineering Education in March 1986, at least 100 reports have appeared that decry the condition of instruction. A typical theme is that of the National Advisory Group of Sigma Xi, the research society:

> Undergraduate education is trapped in an infrastructure that rewards those who devote their resources to research and denies those who devote a significant portion of their resources to undergraduate programs.

The science and engineering "pipeline" both in general and for underrepresented groups was the subject of two of the last three Presidential Addresses of the American Association for the Advancement of Science. Similarly, a workshop in April 1990 sponsored by the Alliance for Undergraduate Education - a consortium of 16 of the Nation's largest public research universities - summarized the pipeline problem and added the following:

> Science education is such an important national problem that research universities must give it high priority.

These facts and opinions belie the thesis that undergraduate students can fend for themselves in learning science, mathematics, and engineering. We deal here with a critical national problem, and NSF can play a larger role than it has in the past in addressing that problem.

THE NSF RESPONSE IN TERMS OF PROGRAMS

The current undergraduate-oriented programs of the NSF respond to the recommendations of the NSB report of 1986. They include laboratory instrumentation, course and curriculum improvement in calculus, in engineering, and in introductory courses, enhancement of faculty expertise through seminars, research by undergraduates, research at predominantly undergraduate schools, and improvement of access to careers for underrepresented groups. The Foundation has also sponsored 25 workshops and studies on science and engineering education.

The workshops and evaluations of the Foundation indicate that these programs have begun to engage faculty in instructional improvement. This is the basic means by which the NSF can achieve "greater attention by faculty to undergraduate instruction. . ." Strengthening undergraduate instruction requires maintaining NSF's current programs and examining other creative activities related to teaching, including:

All schools:

- support for personnel and other costs to develop improved instruction. Pockets of expertise on various aspects of instruction have in general not arisen in either colleges or universities. That important deficiency occurs because there has been no visible means of initiating or sustaining such resources in the infrastructure.
- supporting science and engineering faculty to take leaves of absence to study pedagogy, or to combine research and educational improvement in such a leave. Faculty currently may apply to NSF (through the small Research Opportunities Awards program) for major professional refreshment only in connection with disciplinary research. Creating vitality in science and engineering education requires that we foster those deep pedagogical insights that may be won by lengthy study sometimes far from home.
- mounting comprehensive improvement projects at one site that target faculty development, instrumentation, and curriculum revision. Deep-seated problems at any institution often require that several aspects be addressed simultaneously and coherently.

Two-year colleges:

- flexible programs that would revitalize their faculties professionally or keep them active.
- programs that address the unique articulation problems between two-year colleges and high schools and between two-year colleges and four-year colleges.
- programs that address poor student motivation and preparation and the resulting instructional problems.

The lack of faculty time for creative work on curriculum and scholarship is a major problem. It should be possible for a two-year college faculty member and a colleague at a nearby four-year college or university to develop a proposal for a period of professional work that might encompass disciplinary research, attendance at meetings and classes, pedagogical study, teaching, development of courseware, etc. Such interactions would yield continuing benefits because the local connections would help to solve the curricular articulation and transfer problems between high schools, and two-year and four-year institutions.

Undergraduate institutions:

- support for faculty professional activities at their own schools and involving their own students that includes subjects beyond traditional disciplinary research.
- support for college faculty to create educational materials and otherwise share the teaching insights that they have.
- support for postdoctorals, two-year college teachers, and high school teachers to work with college faculty mentors on projects that combine teaching and research.

These schools have long emphasized teaching and close contacts of students and faculty. The faculty at these schools are mostly Ph.D.'s who - with modest support from NSF - can sustain professional activities at their own schools. Such activities pay off in the classroom in reinvigorating instructional programs and attracting students to science and engineering. Undergraduate faculty should be enabled to engage their own students and nearby secondary school teachers in pursuits beyond mainstream disciplinary research. This will encourage using one's education to attack local problems, to apply science and technology in practical arenas. The products of undergraduate student/faculty research are more than scholarly publications. They include inspiring the student with the desire to become a scientist or engineer, and sustaining the mentor and his or her academic program. The faculty at these institutions, moreover, have insight about how to educate undergraduates, and they should be more strongly involved than they have been in national curriculum reform efforts and the development of curricular materials. The current efforts underway at NSF to support curriculum, course, and laboratory development are crucial for this educational sector.

Doctoral universities:

- create active and personal learning experiences where large numbers of science students must be served, including better preparation of teaching assistants.
- expose general students and prospective elementary and secondary teachers to laboratory science and improved curricula aimed at meaningful learning.
- create structures involving university, college, and high school faculty in scholarship and refreshment activities related to teaching.

Because of competing interests, faculty and other instructional personnel at universities need incentives to devote time and energy to local curricular development. The terms of grants for new curricular work should parallel those of research grants by allowing summer salary for faculty, support for staff and graduate and undergraduate assistants, and travel. Universities have serious instructional equipment problems that are beginning to be addressed by the Instrumentation and Laboratory Improvement Program. Because the universities are our largest centers of learning and have commensurate library, laboratory, personnel, and facilities resources, those resources should be employed to improve science education at non-doctoral institutions.

CONCLUDING REMARKS

The resurgence of science education at NSF, and at the Federal mission agencies that depend on scientists and engineers, responds to the deepening perception by experts and by the public of the difficulties in science education. The U.S. House Committee on Science, Space, and Technology has contributed much to this resurgence, and the approach embodied in the Federal Coordinating Council on Science, Education, and Technology, Committee on Education and Human Resources (FCCSET/EHR), is auspicious. However, NSF represents only 20 percent of the roughly $1.5 billion in Federal math and science education activities and only about 25 percent of the undergraduate education activities. Through the FCCSET/EHR, 11 Federal agencies are working together to develop an effective and integrated approach to precollege, undergraduate, graduate, and general public math and science education. While this report has mentioned some approaches to strengthening undergraduate instruction, it is important to make these investments wisely in the current constrained budget environment and in the full context of the math and science "pipeline."

APPENDIX IV

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Republican Chief of Staff

March 27, 1991

Dr. Frank Press, Chairman
National Research Council
2101 Constitution Avenue NW
Washington, DC 20418

Dear Dr. Press:

In preparing for authorization of the National Science Foundation (NSF) programs, the Subcommittee on Science is reviewing the NSF budget request for fiscal year 1992. Included in this request is a proposal to construct the Laser Interferometer Gravitational Wave Observatory (LIGO). According to NSF, an important justification for proceeding with LIGO is that the project represents the beginning stage of a valuable astronomical observatory.

The Astronomy and Astrophysics Survey Committee of the National Research Council (NRC) has recently concluded a careful assessment of facility needs in astronomy for the next decade. The Survey Committee's report, "The Decade of Discovery in Astronomy and Astrophysics", sets forth a consensus on what new facilities ought to be funded and places these facilities in priority order. Although not included among the recommended projects, LIGO was reviewed, I understand, by the NRC Survey Committee as a potential astronomical facility.

In order for the Subcommittee on Science to determine what action to take on authorization of LIGO, we need to verify whether LIGO was in fact included among the competing astronomical facilities considered by the NRC Survey Committee. We would appreciate receiving this information at your earliest convenience along with any additional findings of the NRC Survey Committee which would assist the Subcommittee in assessing the scientific value and timeliness of proceeding with construction of LIGO. Thank you for your attention to this request.

With kind personal regards and best wishes, I remain,

Sincerely,

Rick

Rick Boucher, Chairman
Subcommittee on Science

RB/Weg

NATIONAL RESEARCH COUNCIL

2101 CONSTITUTION AVENUE WASHINGTON, D. C. 20418

OFFICE OF THE CHAIRMAN

April 12, 1991

The Honorable Rick Boucher
Chairman, Subcommittee on Science
405 Cannon House Office Building
Washington, D.C. 20515-4609

Dear Congressman Boucher:

I am responding to your request for more information about the Astronomy Survey Committee's views on LIGO. I enclose a statement by the committee which has the unanimous support of its members. It carries the endorsement of the National Research Council, under whose process the survey was organized and carried out.

It is interesting to me that it is something of a tradition in the physics community to propose large-scale experiments which push the state of the art and involve instruments of record-breaking power or sensitivity. The motivation is to survey an unexplored region with the hope or expectation that an important discovery will be made. This approach has led to some important breakthroughs and has opened new areas of technology.

Yours sincerely,

Frank Press

Frank Press
Chairman

Enclosure

NATIONAL RESEARCH COUNCIL
COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND APPLICATIONS
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Statement of the Astronomy and Astrophysics Survey Committee

The Astronomy and Astrophysics Survey Committee (AASC) for the 1990s reviewed the material regarding LIGO in the advocacy statement of the Interferometry Panel and considered other material relative to the astronomical importance of LIGO. The committee concluded that the secure scientific goals of LIGO for the 1990s are not astronomical. In the preliminary evaluation, there was not significant support for the astronomical aspects of LIGO among the other large new projects for the 1990s. The AASC is aware that the LIGO project has been favorably reviewed in the Brinkman report on physics and that LIGO has important goals in physics and in high technology. Since the committee's charge was to prioritize astronomical initiatives, the survey committee requested and received permission from the National Science Foundation not to rank or discuss LIGO in the survey report.

Addendum to the
Testimony of
Dr. Rochus E. Vogt

R. Stanton Avery Distinguished Service Professor
and
Professor of Physics
Director, Laser Interferometer Gravitational-Wave
Observatory (LIGO) Project
California Institute of Technology

Before the
Subcommittee on Science
of the
Committee on Science, Space, and Technology
United States House of Representatives
March 13, 1991

This addendum is prepared in response to testimony by Dr. J. A. Tyson. While Dr. Tyson and I agree on the importance of developing LIGO as a detection system for gravitational waves and of opening the gravitational-wave window onto the universe, Dr. Tyson has raised several questions about the LIGO proposal. These questions and our responses can be summarized in the following general way.

1. *Have the source strengths that have been used to guide the LIGO design been over-estimated?*

   While the source strengths circulating in the 70's have been revised downward, the numbers used in the LIGO proposal are based upon the best available analysis and data and are accepted by the expert community and do not disagree with the numbers used by Dr. Tyson.

2. *Can LIGO achieve sufficient sensitivity to be successful?*

   The LIGO proposal lays out a structured program, beginning with detectors orders of magnitude better than currently in use, and leading to detectors capable of studying the most reliably predicted sources.

3. *Can LIGO produce meaningful advances in astronomy and physics?*

   LIGO will observe and study astrophysical phenomena and physical processes inaccessible to any other detection technique and will complement information from other astronomical disciplines.

4. *What is the level of support for the project in the scientific community?*

   In its development phase to date, LIGO has been reviewed and received strong support from physicists, since the technology lies in their domain. However, the ultimate scientific output of LIGO will be of the greatest benefit to astrophysics.

5. *Are there any prospects for technological spinoffs?*

   Not only are there future prospects for technology spin-offs, LIGO has already made significant spin-off contributions.

6. *Should LIGO be constructed on the timescale and in the manner proposed?*

   The present implementation plan resulted from the study of numerous alternatives. Our plan has been endorsed by expert review groups and the National Science Board.

In the following, I will discuss these responses in greater detail, expanding on my earlier remarks and providing additional clarifications.

1. How Strong are the Gravitational Waves?

The perception by many astronomers, particularly those not working in the field of relativistic astrophysics, that the strength of gravitational-wave sources has been over-estimated is due primarily to early estimates: in the early 1970's the first estimates by gravitational physicists and astrophysicists for the strengths of the gravitational waves bathing the earth were indeed too large. Then gradually, over the 1970's and into the early 1980's, better understanding brought about reduced estimates of strengths. Although these estimates were widely discussed at the time, astronomers who have not been active in this field since then may not be familiar with the more recent work.

Over the past fifteen years, a concerted effort by researchers, documented in numerous scientific papers and in the proceedings of nine conferences and workshops, has clarified the situation. The only hope for further understanding is through the detection and study of the gravitational waves themselves, or through new astronomical discoveries with other kinds of telescopes. This situation was also presented to various review committees, and to Subpanels of the Astronomy Survey Committee and of the Physics Survey Committee. Current source estimates were summarized in Appendix A of the LIGO Construction Proposal, submitted to NSF in December 1989, and have been published in expanded form in the scientific literature.

Two important facts about the source estimates should be emphasized:

1. Only one type of source is understood well enough to predict with *fair* confidence how sensitive the LIGO must be to detect several events per year: the spiraling together of two neutron stars that are in orbit around each other. By *fair* confidence, we mean, conservatively, to within a factor of ten.

2. All other sources are uncertain by several factors of ten. (Note that this enormous uncertainty highlights the correspondingly enormous gain in knowledge if and when such sources are detected.) There is a significant possibility (but no certainty) that one or more of these other sources will be ten times stronger than inspiraling neutron stars.

2. Will LIGO Be Able to Detect the Waves?

LIGO has been planned to provide the necessary flexibility to accommodate the uncertainties in source strengths and event rates. The LIGO vacuum facilities, which are by far the major cost elements, are designed to accept a succesion of increasingly sensitive (but low-cost!) detectors. The successive detectors will be paid for out of the normal LIGO operating budget: there will be no need for huge additional investments of funds each time a new, highly improved detector is constructed and mounted inside LIGO. The facilities are flexible enough to allow gravitational-wave searches and observations to be carried out with one set of detectors, while improved detectors are being developed and tested. The detectors will be developed in stages, and each significant advance will be used to search for new gravitational-wave signals. This approach is analogous to that of optical astronomy, where large telescopes have been continually improved through the development of more sensitive focal plane instruments (for example, sensitive CCD detectors have replaced photographic plates) even though the basic telescope remains unchanged.

We have defined three sensitivity goals for LIGO:

1. *Early detector goal*: The first detectors will have adequate sensitivity to detect and study waves ten times stronger than the estimate for inspiraling neutron stars. This early detector goal is adequate for a significant possibility, but not high probability of detecting gravitational waves. This requires an improvement of 3,000 (in contrast with 10,000 quoted by Dr. Tyson) over the performance of current prototypes. We expect to achieve this improvement with the first LIGO detector. In what is necessarily an oversimplified description, a factor of 100 improvement will come from the fact that LIGO is 100 times larger than our prototype; the remaining factor of 30 will come from increasing the effective laser power, and enhancing the seismic isolation. We have a concrete design for the detectors to achieve this goal, a design that has been examined by expert reviewers who reported back positively to NSF. We will also benefit from a development period of at least five years (the facilities construction time) before the first detector need be installed.

2. *Intermediate detector goal*: These detectors will have adequate sensitivity to detect waves at the estimated strength for inspiraling neutron stars. At this level we are fairly confident of seeing gravitational waves. This intermediate goal requires a further improvement of ten over the early detector. The intermediate-level detectors are in the conceptual-design state and the designs that we have for them will not require any major breakthroughs in technology. They use high-power solid-state lasers, mirrors, optical designs, and antivibration systems that are being developed not only by the LIGO team, but by others in academia and industry. Experts in the relevant technologies have scrutinized the technological challenges posed by such detectors, and agree with us that they can be met.

3. *Advanced Detector Goal.* These detectors will be sensitive to waves ten times weaker than the inspiraling neutron star level. Although these detectors require technological development, they do not require large extrapolations from current capabilities or any new physics. It would be very surprising if gravitational waves were not found before such detectors are in operation.

While it will be a challenge to reach these goals, we are convinced it is far less difficult than Dr. Tyson describes. Between its initial operation in 1983 and today (8 years), the Caltech 40-meter laser-interferometer detector has improved by a factor 30,000, bringing it to about the same sensitivity as the best detectors in the world. A further improvement of 30,000 will bring us to the intermediate detector goal, where LIGO is likely to begin significant gravitational-wave observations. This second 30,000 will require a much larger effort than the first. There is no way that it can be achieved in a 40-meter facility. It can only be accomplished with the 4-kilometer LIGO facility. The committees of experts on the relevant technology, who have examined the LIGO project and recommended its funding, are convinced that it is an achievable goal.

3. The Scientific Payoffs from LIGO

What science could LIGO do, once it has detected gravitational waves, and what further efforts would be required to reap the waves' scientific payoff? This question must be answered in two parts: first, in the absence of any European LIGO-scale detectors to form a complete network with LIGO, and then as part of a complete network.

The two-facility LIGO by itself would be capable of extracting only half of the available information from the gravitational waves—one of the waves' two waveforms. This would be like a stereo system with one of its speakers turned off. One can do a great deal with half the information. For example, one can say that the source of the waves lies near a curve on the sky, and one can learn much about what the source is and what it is doing from the observed waveform. To measure both waveforms (in my analogy, to turn on both stereo speakers) and to identify the source's location will require at least a third facility. We are working together with our European colleagues to make such a network a reality.

Although many studies will involve both gravitational and electromagnetic waves, this is by no means required. The gravitational waveforms by themselves carry rich information about their source. One of the most interesting of the expected gravitational-wave sources is the inspiral of two black holes that are orbiting each other, followed by their merger to form a single black hole, followed by bell-like vibrations of the final black hole. Great effort has been expended by theoretical physicists, during the past fifteen years, to deduce what Einstein's general relativity theory predicts about such black holes and the waves they emit. This effort has produced an unequivocal prediction for the waveforms from the inspiral and vibration, but not yet for the merger. Sophisticated supercomputer simulations are being planned, with financial support from the National Science Foundation, to produce merger predictions.

One of the two predicted wave forms, i.e. signal amplitude versus time (with a crude guess for the merger portion) is shown in Figure A. Each of the peaks and valleys in the wave can be interpreted by the physicists to unravel the motion and behavior of the black holes.

In the absence of any observations with other kinds of telescopes (and with a precision that will depend on how strong the waves are), one can extract the following information from the waveforms:

- One can infer with confidence that the source was two black holes and not something else.
- One can infer the distance to the source, the masses of the two black holes, and the mass and rate of spin of the final black hole.
- Most importantly, from a physicist's viewpoint, one can compare the simulations with the observed merger waveforms, and by that comparison, one can test our theoretical understanding of how gravity behaves when it is so strong that it is highly nonlinear.

These studies require no other (non-gravitational) observations at all. They could be the rich harvest of LIGO alone, even without a European partner. As this example illustrates, the waveforms carry enough information that they often, and perhaps typically, will tell us what the source was, without any help from other observations. Furthermore, it must be emphasized that many of the natural phenomena reflected in gravitational waves may be invisible to traditional astronomical telescopes or detectors, and will be a stand-alone science.

When both gravitational and nongravitational observations are available, their combination will produce a much enhanced picture of what is going on. Such joint observations can be made if astronomers can identify where the gravitational source is in our universe, and thereby determine which source of light, radio waves, or x-rays coincides with it. This location can be determined by triangulating on the source using the LIGO plus at least one international partner. We have carried out simulations of LIGO plus one detector in Western Europe. Those simulations predict that this three-site network will typically be able to pinpoint the source on the sky to within a region about the size of the moon. (For stronger sources or a larger network of detectors, the precision will be better.) This is poor precision by the standards of today's radio and optical telescopes. However, it is the precision of radio astronomy around 1950, when the first optical identifications of radio sources were achieved; and it is likely to be sufficient precision to provide optical or radio identifications for *some* gravitational-wave sources.

4. Support for LIGO in the Astronomy and Physics Community

It is generally accepted, in both the astronomy and in the physics communities, that until LIGO actually detects gravitational waves, it is a physics facility. That is why LIGO is funded out of the physics section of NSF, not the astronomy section; that is why all the scientists developing LIGO are physicists, and almost all of the scientists who have reviewed LIGO for NSF and passed judgment on it are physicists. In its development phase, LIGO requires physics and engineering technology that is unfamiliar to most astronomers. A similar situation existed when radio telescopes were pioneered by electrical engineers and physicists in an era when typical astronomers had little interest in, or enthusiasm, for them. I would not be surprised if most of the of 60 astronomers sampled by Dr. Tyson had little familiarity with LIGO.

The LIGO project includes many more scientists than the four enumerated by Dr. Tyson. The experimental programs at Caltech and MIT currently involve 13 full-time PhD-level scientists, 8 graduate students, and 8 undergraduate students; collaborations with Stanford University, University of Colorado, and Syracuse University involve more than a dozen other scientists and graduate students. In parallel with this experimental effort, approximately 10 PhD scientists and an equal number of graduate students at various universities are carrying out numerical simulations of gravitational-wave sources on supercomputers, to provide guidance as to the details of the waves that we might expect—guidance that will be important in the design of LIGO's data analysis algorithms. Including these theorists, the present LIGO "user community" includes about 30 scientists at the PhD level and about 25 graduate students.

These numbers will grow significantly when construction funds for LIGO are approved, and when gravitational-wave detectors begin to operate in LIGO. By the time LIGO becomes a mature observatory, we expect contributions from at least several hundred scientists. These will include experimental physicists (working on new detectors and technology), theoretical physicists (simulating sources on supercomputers and studying the nonlinear physics of gravitation via comparisons between LIGO data and simulations), applied mathematicians (developing new algorithms to search for signals in LIGO data), and astrophysicists (carrying out searches in the data, and using the signals that they extract from the data to study the properties of the sources).

5. Technological Spinoffs

Because they are outside the normal interest of most astronomers and physicists, the technological spin-offs from LIGO are not widely recognized in the academic community. As was discussed in the earlier testimony, the LIGO development has already produced technological advances which are finding application in both science and industry and will continue to do so. If history is any guide, we should recognize that frequently the most important technology developments from a research project are much different from what one would have predicted at the outset.

6. Should LIGO be Constructed on the Timescale and in the Manner Proposed?

Dr. Tyson suggests that "...it is premature to commit to a full-scale LIGO (as proposed) before demonstrating the required technologies first on the existing prototype, and then on a single LIGO Phase A facility ("half- LIGO"). There is no strong technical justification for building two LIGO facilities (this proposal) in the U.S. at this time...." Development and refinement of the basic LIGO technology has taken place for more than a decade, and will continue. However, considering the present performance, the rate of progress, the time needed to construct the LIGO facilities, and the experience and maturity of the scientific and engineering team, the right time to begin construction of the LIGO is now. This judgment has been shared by the many review groups and the National Science Board that have analysed the LIGO in more detail. The next large factors in sensitivity improvement require the long-baseline facilities of the LIGO; without them the field will remain a technology development program without a scientific focus.

The notion of building only one facility is not new. Initial reviewers of the LIGO made this suggestion, but it is fundamentally flawed. No believable scientific observations can be made with a single facility. The diagnostic techniques to develop LIGO technology and to establish confidence in the detection methods require two sites. We have concluded, and won the consent of reviewers, that it would be an injudicious use of resources to build only one facility and that a necessary condition for the project to go forward was to guarantee the availability of two facilities. In this regard it is important to note that the cost of the second LIGO facility only represents about 30% of the overall cost of the project. Because of the need for two facilities I have personally, and with the help of the NSF, attempted to interest the Europeans in cooperating in a program under single management, but without avail. The technical readiness of the European projects lags that of the U.S. LIGO. Decision-making on the multitude of existing technical options for a LIGO facility (a facility never constructed before) requires a degree of centralized direction which has been rejected by our European colleagues. The U.S. takes no excessive risks in assuming the lead in the global program of gravitational-wave detection, since LIGO can operate effectively in an autonomous and scientifically rewarding fashion before the European facilities come on line. Subsequent joint operations will be amenable to coordination in a less centralized organizational mode.

I believe the United States should not be afraid to be a pioneer and leader in opening a new field of science, in daring to make breakthroughs. To timidly or complacently engage in only the known and familiar, to pursue only enhancements of that which exists, condemns us to mediocrity. And we certainly should not shackle U.S. leadership by asking it to march in rigid lockstep with the rest of the world.

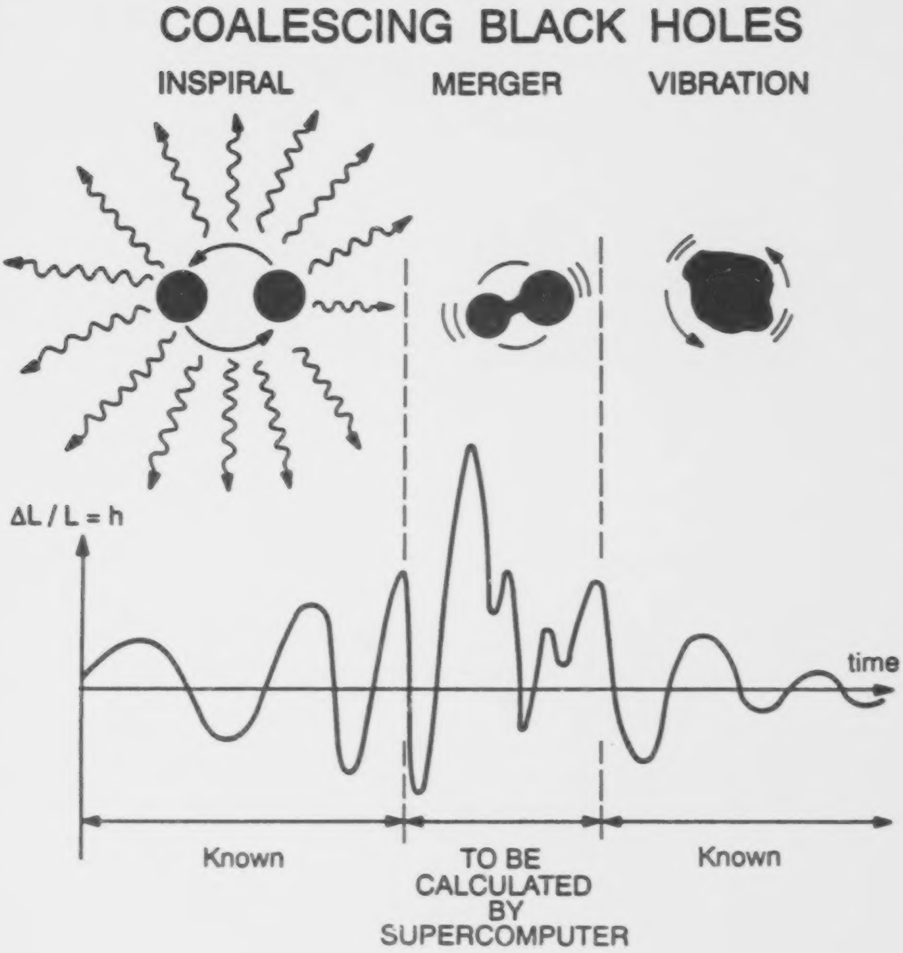
COALESCING BLACK HOLES
INSPIRAL
MERGER
VIBRATION
ΔL / L = h
time
Known
TO BE CALCULATED BY SUPERCOMPUTER
Known

Figure A

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600 Mountain Avenue
Murray Hill, NJ 07974-2070
908-582-3000

March 21, 1991

The Honorable Rick Boucher
Chairman, Subcommittee on Science
United States House of Representatives
Suite 2320 Rayburn House Office Building
Washington, DC 20515

Dear Representative Boucher,

Enclosed is the final copy of my written testimony given before your Subcommittee on Science on March 13. Also enclosed is a professionally drawn copy of the graph I submitted (together with a caption), and an addendum to my testimony. I hope my testimony has been helpful to Congress.

As you may have gathered there is some controversy in the scientific community, once you get beyond the gravity physics community, on the priority of LIGO. Naturally every sub-discipline would like to see it's favorite machine built. In the case of the gravity physics community, they apparently rated Gravity Probe B and other gravity tests above LIGO (then called the Long-Baseline Gravitational-Wave Facility) in the NAS/NRC Physics Survey "Brinkman" report (1986). I attach a copy of the relevant pages for your information. Since LIGO is now being justified on the basis of the astronomy it might undertake (note change in name to "Observatory"), many in the broader astrophysics community feel that it would be good to have a wider review of the chances of success and the usefulness of LIGO to astronomy.

Personally, I would like to see a world-wide network of LIGO detectors built and operated effectively under a common management. Unfortunately, I think we are a long way from achieving this goal, for technical and geopolitical reasons. Most of the physicists and astronomers I interact with would rate LIGO above the SSC and the Space Station. But they (and I) rate LIGO way below the several other initiatives of comparable or lower cost which are guaranteed to expand our horizons in physics and astronomy. With regard to the priorities of the astrophysics community, I think the best current indicator would be the NRC/ASC "Bahcall" report. The major initiatives described there will put US astronomy and astrophysics back on the competitive track, and they will have large user communities.

The US scientific infrastructure is definitely in bad shape, particularly in comparison with Europe and Japan. It is not just a K-through-12 problem, it is K-through-Researcher.

Although basic research in industry in recent years has, understandably, become more directed and "bottom line", when I visit US University research labs and National Observatories I see a situation which is much worse. I think this Nation must decide whether it wants to invest in its short-term or its long-term security. NSF Physics and Astronomy base budgets, when corrected for technical inflation, have been falling for some years now. A doubling of the NSF budget over the next few years is, I think, critically needed. It seems to me that the most efficient way of funding US science is to ask the scientists themselves to prioritize. Mechanisms which avoid the review process are, in my view, both wasteful of the taxpayers dollars and discouraging to the scientific community. What is your feeling on the subject of earmarking? Is legislation against earmarking possible?

It is comparatively easy to "sell" large and costly initiatives. Small science and individual research grants get lost in the noise. I have seen this sociological phenomenon in industry as well. I don't know what the answer is. Perhaps if Congress were to both double the NSF budget and indicate its concern over this small science issue a more balanced and healthy science program would result. Perhaps something like an "innovation contest" instead of the all too common "sure thing" contest. You would get more people thinking creatively and more risk-taking. More neurons per dollar.

Best wishes for success in your important and difficult decisions.

Sincerely,

Tony

J. A. Tyson

PHYSICS THROUGH THE 1990s

Gravitation, Cosmology, and Cosmic-Ray Physics

Panel on Gravitation, Cosmology, and Cosmic-Ray Physics
Physics Survey Committee
Board on Physics and Astronomy
Commission on Physical Sciences, Mathematics, and Resources
National Research Council

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This brief section summarizes the findings and principal recommendations of this report for each of the fields studied. The basis of the recommendations is solely scientific merit. We asked: what are currently the most important questions, and the most promising ways to get answers? Cost considerations played a major role only when comparing various approaches to a single scientific question.

Recommendations such as these tend to focus on large new facilities and to understate the importance of ongoing research by individuals and small groups. It is important to keep in mind that the ideas and basic research of small groups constitute the core of physics research in this country—a highly successful enterprise. Indeed, only out of these studies grow the initiatives and needs for large facilities. We wish to emphasize that U.S. research in each of the fields surveyed in this report is of high caliber. In implementing any of these recommendations care should be taken that productive ongoing work remains healthy.

Additional recommendations appear at the end of Parts II, III, and IV of this report. The scientific perspective and justification for these recommendations are presented in the sections titled Highlights and Opportunities.

RECOMMENDATIONS ON GRAVITATIONAL PHYSICS

Space Program in Gravitation

In the last two decades gravitation has evolved from a predominantly theoretical subject to a state where experimental work is making substantial contributions. Several effects predicted by general relativity have been checked experimentally and found to agree with theory to better than 1 percent accuracy. Also, basic assumptions such as the metric nature of gravity and the equivalence principle have been tested experimentally with high accuracy. Much of this rapid experimental progress is due to the careful application of space techniques to precision solar-system measurements; we are fortunate that the National Aeronautics and Space Administration (NASA) has recognized its special capabilities for experimental gravitation research. Noting that much fundamental work still remains, we recommend that NASA pursue a vigorous gravitational-physics program in the years ahead in order to maintain U.S. leadership in this fundamental area of physics.

- Test for "magnetic" gravitation
    - Relativity gyroscope experiment (Gravity Probe B)
- Improve solar-system tests
    - Improve laser and radar ranging to the Moon and planets
    - Improve accuracy of ranging to future planetary spacecraft
- Study ideas at frontiers
    - Millihertz gravity waves and second-order tests

Ground-Based Studies in Gravitation

Most ground-based research in gravitation is focused on the detection of gravitational waves. These difficult experiments are driven by the need to test a basic prediction of general relativity and by the hope to one day have an entirely new technique for exploring fundamental processes such as gravitational collapse. The National Science Foundation (NSF) has played an important role in fostering this work and is currently considering a major initiative—a Long-Baseline Gravitational-Wave Facility. We have studied this idea and enthusiastically endorse it, assuming that other ongoing work of high quality will not be adversely affected. We recommend that the NSF enhance its leadership in gravitation research by funding the Long-Baseline Facility, while continuing to support a vigorous program to search for gravitational waves with resonant bar detectors.

- Extend the search for gravity waves
    - Build 5-km-baseline interferometers (10 Hz to 10 kHz)
    - Improve resonant bars

Gravitation Theory

Theory plays a uniquely important role in gravitation. By exploring a wide range of theoretical possibilities it guides the field, pointing experimenters to the key questions. Currently, fundamental questions are being asked with important connections with other areas of physics and with mathematics. We urge that a healthy level of activity be fostered in this essential part of gravitation research.

Addendum to the Testimony of Dr. J. Anthony Tyson

Optical Physics Research Department
Physical Research Laboratory
AT&T Bell Laboratories

Before the
Subcommittee on Science
of the
Committee on Science, Space, and Technology
United States House of Representatives
March 13, 1991

Modern physics and astronomy research pushes technology development and trains technical manpower. Many of these trained researchers end up in other areas of our Nation's workforce, enhancing our technologies and economic competitiveness. I am particularly familiar with the often intense collaboration between industry and fundamental physics and astronomy researchers, in developing state-of-the-art instrumentation. The resulting advances in technology not only enrich our science but also find their way into US products. An important ingredient in this process is the cross fertilization of various fields of science. Physics and astronomy, for example, have benefited from each other's discoveries and science-driven technology development. There is a continuum of endeavor from physics to astronomy. Nowhere is this synergism stronger than in the juncture between these fields, astrophysics. Along with several other exciting initiatives, LIGO sits on this border between physics and astronomy. It is understandable that many physicists would consider LIGO ultimately an astronomy experiment, and many astronomers would think of LIGO as a physics experiment. But until a world-wide network of operating LIGOs is a reality and astronomical detections are routinely made, LIGO will remain fundamentally a physics *experiment*.

The decision to go ahead at this time with the full-scale LIGO revolves, I think, about two basic questions:

1. The science, physics or astronomy, which may emerge from a successful LIGO. This naturally must involve issues of technical feasibility and scientific justification. As such, it should involve a dialogue within the combined physics and astronomy communities. In this connection it is crucial that astrophysicists, who study possible sources of gravitational waves (such as neutron stars and black holes), be brought into the discussion. Until now, there has been remarkably little debate of the LIGO proposal in the astrophysical community.

2. The priority this scientific community places on LIGO, and where it ranks LIGO with respect to the other major initiatives it wants to undertake. The issue of the health of US science naturally arises here, together with the big science vs. small science issue. When corrected for technical inflation, the NSF physics and astronomy base budgets have actually been declining in recent years. In times of fiscal constraint this strongly influences opinions regarding new starts on major initiatives with high risk. Regarding the priorities of the astrophysics community, perhaps the best current measure is the recently completed NRC ASC "Bahcall" report.

I would like to emphasize something I said in my oral testimony: LIGO, or a world-wide system like LIGO, is in my opinion our best shot at opening this new window on the universe. Admittedly it will not be easy, and there is a fair chance that it will detect nothing. The accompanying graph "LIGO Detector Sensitivity" is my reading of the current situation and the challenge. The goal is to march as far down this graph as possible by improving the detectors. [Currently there exist gravitational wave detectors using a different technology (made from a solid bar of aluminum) in the US, Germany, and Italy which have sensitivities intermediate between the 1991 LIGO prototype and the early LIGO goal shown in the figure. These "resonant-bar" detectors, while reasonably sensitive, cover less of a frequency band than LIGO would, and thus yield less information about the source of that radiation.] If, years from now, LIGO achieves a 100,000-fold increase in sensitivity, we will have a very interesting addition to the array of tools we have for studying the universe. The main question in my mind is whether it is best to scale up to a full LIGO at this time, or wait until the efforts to reduce the noise in the LIGO prototype are successful.

To a certain extent this kind of decision is a matter of "style" or expediency. In any case it is crucial for the realization of the science that the physics and high technology development work connected with LIGO continue. Any effective detector of cosmic gravitational waves necessarily involves multiple facilities. I agree with Dr. Will that an effective gravitational wave observatory would have to consist of a world-wide network of at least three or four LIGO-like facilities under common management.

My analysis of LIGO was based in part on voluminous data kindly supplied to me by the LIGO researchers. Subsequently, they have described to me their plans to reduce the noise. I believe my analysis of the LIGO experiment, including the current state of the LIGO prototype, is correct. This is summarized in my figure and its caption. This shows that it will be difficult but not impossible to reach the LIGO goal. At that point (early LIGO goal) it will take at least another factor of ten increase in sensitivity to have a reasonable chance of detecting a binary neutron star inspiral. Physics tells us that there are some sources of fundamental, irreducible noise. Certainly the excess noise in the current LIGO prototype is *not* fundamental in this sense. Given enough work it should be possible to reduce the noise. Although there may be setbacks along the way, these plans by the LIGO group form a sensible line of attack, and I wish them well. The LIGO group has some outstanding experimental physicists. If it can be done, they will probably do it.

The undisputed detection of gravitational waves from an astronomical source by an Earth-based detector array would presumably carry with it a Nobel Prize in physics. It seems to me that Taylor's measurement of the effect of gravitational waves from a known celestial source also qualifys for such an award! As a result of his work it is clear beyond reasonable doubt that gravitational waves exist and that we can calculate their emission. This removes much (but not all) of the physics justification for a search for gravitational waves using an Earth-based detector system. Most theorists now agree that the estimates for the source strength of the death spiral of binary neutron stars is fairly accurate, although how often these events might occur is naturally somewhat uncertain. Indeed, some astrophysicists who responded to my survey felt that we may have to search out to greater distances. This would have the effect of lowering the neutron star inspiral line in my graph all the way to the bottom of the graph. Therefore, even if the early LIGO goal is attained, the ability of LIGO to detect the only certain source of gravitational waves is in some doubt. While it is reassuring that there is at least one potential type of cosmic gravitational waves known to exist, it will be the unexpected discoveries in this new window on our universe which will ultimately justify LIGO.

What will we learn when we *do* detect a gravitational wave event? Many astrophysicists feel that the interpretation may be complicated. Gravitational waves originate only when there are complex mass motions of the kind that probably occur in cataclysmic events. The resulting waves, if detected, would be new information about the densest and most obscure objects in our universe, but may also be difficult to decipher. I hope that nature is not unkind. Surely this is no reason not to look! The question is really what our priorities are now.

It would be helpful to have more discussion of LIGO in the astrophysics community. At a time when the real base budgets in NSF physics and astronomy are decreasing, most University scientists apparently feel that high risk big science initiatives should be postponed. One of the recurrent themes in the response to my survey is the sorry state of funding for individual scientists. An example: "The people that get squeezed out of the grants programs are the young and imaginative people --- that's where progress is going to come." On a personal note, I must say that this review has been quite painful: I have friends on both sides of this LIGO issue. Somehow we have to find the resources to support risk and innovation on on all scales, from the cleverness of the individual researcher, to the larger initiatives for facilities guaranteed to produce wholesale science, to the risk and promise of occasional big science projects.

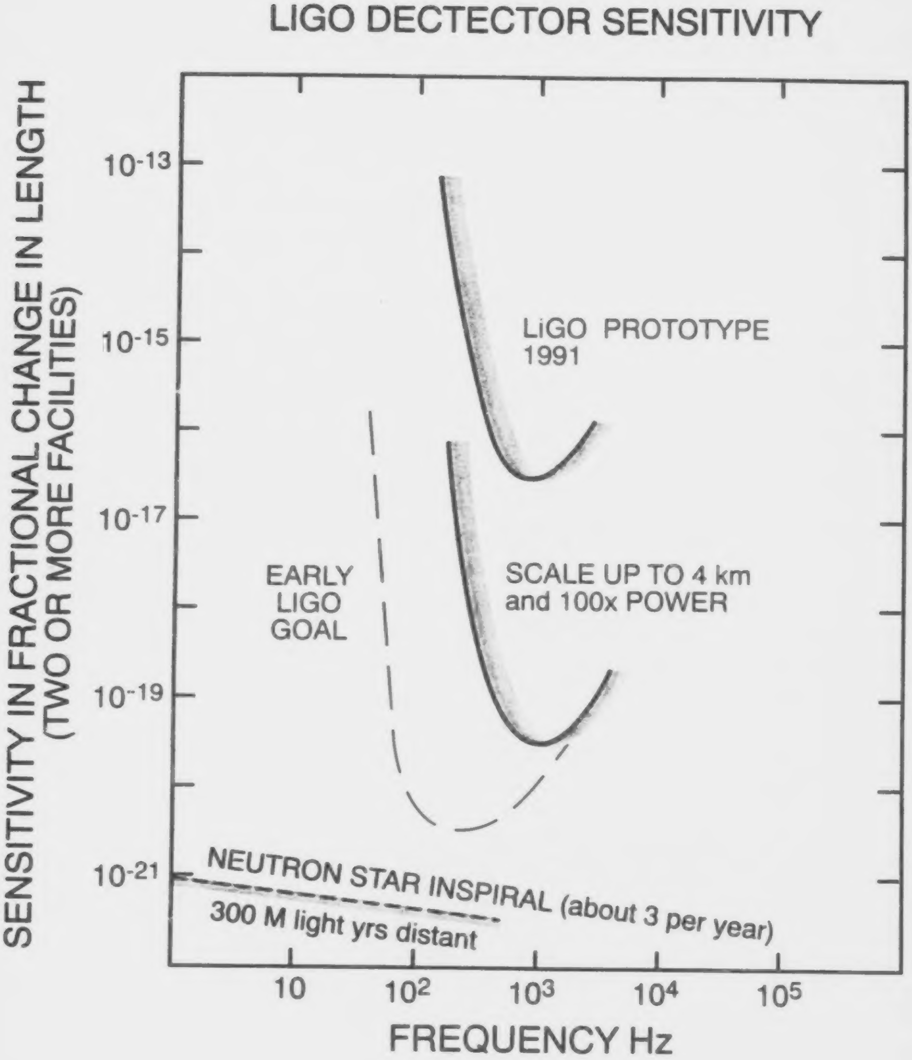
LIGO DECTECTOR SENSITIVITY
SENSITIVITY IN FRACTIONAL CHANGE IN LENGTH
(TWO OR MORE FACILITIES)
10^{-13}
10^{-15}
10^{-17}
10^{-19}
10^{-21}
LiGO PROTOTYPE
1991
SCALE UP TO 4 km
and 100x POWER
EARLY
LIGO
GOAL
NEUTRON STAR INSPIRAL (about 3 per year)
300 M light yrs distant
10
10^2
10^3
10^4
10^5
FREQUENCY Hz

Figure Caption

This figure shows my reading of the status of the LIGO project in early March 1991, for the detection of bursts of gravitational waves: the status of the LIGO prototype; what would be achieved by scaling up to 4km now; the stated goal for LIGO; and the strength of the only certain sources. Sensitivity (fractional change in length) is plotted on the vertical axis. Advances in sensitivity move you down the graph. The operating frequency (in Hz) is plotted horizontally. The detector sensitivity curves are for the case of a coincident detection by at least two LIGO detectors: 90% confidence of reliably detecting three real events per year. This would require at least two LIGO facilities widely separated. At least three facilities would be required to extract useful physics from an event, in general. The 1991 Caltech LIGO prototype (with its current internal noise) [upper shaded curve], when scaled up to 4km and 100x the effective power, results in the roughly 1000x improvement in sensitivity shown [shaded curve marked "scale up to 4km ..."]. On the other hand, elimination of the excess internal noise in the LIGO prototype would result in the sensitivity curve shown as a dashed line ["Early LIGO goal"]. Note that this would be within a factor of ten of reliable detection of the approximately three expected neutron star binary deaths per year out to a distance of 300 million light years. Occasional stronger events at a level above 10^{-20} might occur, but their rates are probably low (one per ten or thirty years). Most gravitational wave burst events are likely to fall off the bottom of this graph.

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600 Mountain Avenue
Murray Hill, NJ 07974-2070
908-582-3000

April 1, 1991

The Honorable Rick Boucher, Chairman
Subcommittee on Science
2319 Rayburn House Office Building
Washington, DC 20515

Dear Mr. Chairman,

As a witness before the Subcommittee on Science on March 13, 1991, I have edited and am returning the hearing transcript forwarded to me for review. I would also like to request that the following information be included in the hearing record:

==

Page 107 Lines 2436-2441

Proposed wording:

The question is whether to build two or one big facility. It must be emphasised that there are four distinct milestones which must be achieved before you have a LIGO "observatory": (1) proof of concept (could LIGO work, *in principle*), (2) achievement of design goal in prototype, (3) achievement of design goal in a single 4km scaled-up facility, and, (4) proof of detection of significant gravity wave signals in a two-facility system.

The LIGO experiment has, to date, attained only milestone #1. Milestone #2, when attained, could be used as justification for a somewhat larger facility. This larger single facility, costing perhaps $100M, would be required to show that the full 2-facility system could work (milestone #3). Finally, after demonstrating the working technology in a single large facility, the argument could be made at that time to build a second large facility. After that has been in operation for some time, milestone #4 might be achieved. If milestone #4 were eventually achieved, then four large facilities around the world would be required to make it an observatory.

==

I understand that this letter may be inserted in the transcript as an appendix and referred to by footnote in the main text.

Sincerely,

Tony

J. A. Tyson

APPENDIX V

March 11, 1991

Honorable Rick Boucher
Chairman, Subcommittee on Science
2319 Rayburn Building
Washington, D.C. 20515

Dear Mr. Chairman:

On behalf of the Engineering Education Coalition, we submit the following views on the Fiscal Year 1992 budget request for the National Science Foundation. We ask that our statement be made part of the Subcommittee's hearing record on the NSF reauthorization.

The Engineering Education Coalition is comprised of the American Society for Engineering Education (ASEE), including its Engineering Deans Council, the National Association of State Universities and Land Grant Colleges (NASULGC) and the National Society of Professional Engineers (NSPE). The Coalition is committed to addressing common issues affecting engineering education and research.

The National Science Foundation plays a vital role in the improvement of engineering education and research. Through its research activities, the Foundation is enabling university researchers to make breakthroughs in such areas as intelligent manufacturing, advanced materials and microelectronic devices. Through its education activities, within both the education and research directorates, the Foundation is promoting significant changes in engineering curricula, improving faculty preparation, and helping expand the engineering student pipeline from precollege through the doctoral level.

The Engineering Education Coalition fully supports Congressional and administration efforts to double the Foundation's budget, including the proposed 17.5 percent increase for FY 1992. We also endorse enhanced support for individual investigators, as well as sustained support for the multi-disciplinary engineering centers. We focus our specific comments on three areas: the two interagency research initiatives and engineering education activities.

The High Performance Computing Initiative. The Engineering Education Coalition is most supportive of the Foundation's major role in this important interagency activity, centered in the Computer and Information Science & Engineering (CISE) directorate. We believe Foundation involvement will have enormous impact on research and education in all technical fields. We are concerned, however, that NSF has not included the Engineering Directorate in its FY 1992 program. While this will not preclude engineers from working in the initiative, it could limit the program's effectiveness.

For example, the Engineering Directorate has well-established programs in high-speed electronic and optical device development, the area that historically has driven advancements in computational and communications speed. Another Engineering program that is not included in the initiative is the application of high performance computers to simulate large-scale engineering problems. This is valuable for substantially reducing the design costs and time required for developing such systems. Thus, with participation of the Engineering Directorate, we believe, the interagency program gains important expertise and the cross-disciplinary enrichment that the engineering programs would provide.

U.S. Global Change Research. The Coalition also strongly supports this major government initiative, but is concerned that a valuable opportunity will be missed by not including the Engineering Directorate. While the current focus of the global change initiative is on observation of phenomena, that will soon need to be supplemented by mitigation research and strategy development, as well as by design and development of new remote sensing instrumentation. Both of these areas are supported through the Engineering Directorate. As with the high performance computing initiative, we believe participation of the Engineering Directorate will substantially strengthen NSF's ability to meet the goals of the global change program.

Given the important contributions that the Engineering Directorate could make to these national initiatives, we hope the Subcommittee will consider recommending that NSF include the Engineering Directorate in the 1992 interagency plans.

Engineering Education Support. As noted earlier, NSF provides vital leadership in improving engineering education. The Coalition is most supportive of the education funding increases proposed in the FY 1992 budget at all levels of education. We are especially supportive of new funding within the Engineering Directorate to sustain and expand the engineering education coalitions--projects designed to promote major, long-term improvements in undergraduate education--as well as continued support for the engineering graduate traineeships for women, minorities, and the disabled. As you may know, the engineering and biological & behavioral sciences directorates have taken leadership within the Foundation to develop traineeship programs.

The Coalition would like to thank Members of the Science, Space and Technology Committee for their commitment to an agency-wide traineeship program at the Foundation, as articulated in the Excellence in Mathematics, Science and Engineering Education Act of 1990 (P.L. 101-589). We were disappointed that funding for the program was not included in the FY 1992 budget request and hope that can be remedied through the appropriations process.

Thank you for considering our views on these matters. If we may provide you with additional information on the Coalition's views, please contact any of our member organizations.

Sincerely,

V. David VandeLinde

V. David VandeLinde
Dean of Engineering
Johns Hopkins Univ.
Coalition Chair
ASEE/EDC Representative

Roger Eichhorn

Roger Eichhorn, P.E.
Dean of Engineering
Univ. of Houston
NSPE Representative

Robert L. Clodius

Robert L. Clodius
President
NASULGC

cc: ✓Rep. George E. Brown, Jr.
Rep. Robert S. Walker
Members, Science Subcommittee

AAES

AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES
1111 NINETEENTH STREET, N.W. • SUITE 608 • WASHINGTON, DC 20036-3690
(202) 296-2237 • FAX (202) 296-1151

March 25, 1991

The Honorable Rick Boucher
Chairman, Subcommittee on Science
Committee on Science, Space, and Technology
U.S. House of Representatives
2319 Rayburn House Office Building
Washington, DC 20515

Dear Mr. Chairman:

I would like to submit the following statement on the Fiscal Year 1991 Budget for the National Science Foundation, on behalf of the American Association of Engineering Societies. We ask that this statement be made part of the record for the NSF authorization.

Thank you.

Sincerely,

Martin Hight
Manager, Government Relations

AAES

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AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES

STATEMENT ON

AUTHORIZATION FOR THE NATIONAL SCIENCE FOUNDATION

March 25, 1991

The American Association of Engineering Societies (AAES) is a multidisciplinary organization of engineering societies dedicated to advancing the knowledge, understanding and practice of engineering in the public interest. The member societies of AAES represent more than 600,000 engineers in industry, government and education.

AAES strongly supports the NSF budget request of $2.7 billion for FY 1992 and endorses the plan to double the budget by FY 1994. The NSF budget funds basic engineering research and education programs that are vital to the United States' long-term economic health. We encourage Congress to approve the budget request and to sustain a high level of support for NSF in future years. Within the budget request, there are three areas in which we would like to focus: the two interagency research initiatives, and engineering education activities.

The High Performance Computing Initiative. AAES supports the Foundation's major role in this important interagency activity, including leadership by the Computer and Information Science and Engineering (CISE) Directorate. We believe the Foundation's involvement will have an enormous impact on research and education in all technical fields. We are concerned, however, that NSF has not included the Engineering Directorate in the FY 1992 program. This will not prevent engineers from participating in the initiative, but might limit the program's effectiveness.

The Engineering Directorate has at least three programs that would provide great value to the multi-agency initiative and complement the strengths of the CISE directorate. The Solid State & Microstructures Program within the Engineering Directorate supports research into the design and fabrication of microelectronic devices that are used in high performance computers. The Chemical & Thermal Systems Division focuses on developing and fabricating better materials for computer devices. And the Communications and Computational Systems Program supports development of the algorithms that tell a computer system what to do and enable scientists to use the full capabilities of the system. We believe these programs in the Engineering Directorate would provide valuable expertise, as well as cross-disciplinary enhancement for the initiative.

Global Change Research. AAES strongly supports this important government initiative, but is also concerned that a valuable opportunity will again be missed by not including the Engineering Directorate. In the observation of phenomena, the Directorate's expertise includes research, design and fabrication of advanced remote sensing devices, as well as the use of large-scale computing systems to speed collection and analysis of data and enable refinement of the global change models. The Directorate also supports research in several key mitigation adoption areas, such as improving machine efficiency by reducing friction, creating high-strength recyclable materials, and improving the efficiency of combustion, electrical power systems and chemical reactions. As with the high performance computing initiative, we believe participation of the Engineering Directorate will substantially strengthen NSF's ability to meet the goals of the global change program.

In light of the substantial contributions the Engineering Directorate could make to these two major research initiatives, we request the Subcommittee to consider recommending that NSF include the Engineering Directorate in the 1992 interagency programs.

Engineering Education. AAES is also fully supportive of the education funding increases proposed in the FY 1992 budget for precollege through graduate levels. We particularly endorse the efforts of the Engineering Directorate which plans to expand the Engineering Education Coalitions program -- aimed at promoting major improvements in undergraduate education -- as well as sustain its fellowship and traineeship programs at the graduate level.

Given last year's authorization for a new Foundation-wide graduate traineeship program, approved through the leadership of the Committee, we were disappointed that funding for the activity was not included in the Fy 1992 budget request. We hope that might be remedied through the appropriations process.

The AAES appreciates your consideration of our views. If we may provide you with additional information, please let us know.

AAES

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ABOUT AAES

AAES Mission

The American Association of Engineering Societies is a multidisciplinary organization of professional technical societies dedicated to advancing the practice and utilization of sound engineering in the public interest. AAES serves as a clearinghouse for communications within the engineering community and in cooperation with its members provides technical advice on public policy issues of national interest.

AAES 1991 Priority Objectives

o Promote U.S. Economic Competitiveness on a Global Scale

o Continued Leadership Role in Coordinating and Promoting Pre-College Math and Science Education.

AAES Membership

Member Societies

o American Indian Science & Engineering Society
o American Institute of Plant Engineers
o American Nuclear Society
o American Society for Engineering Education
o American Society of Civil Engineers
o American Society of Mechanical Engineers
o Institute of Electrical & Electronics Engineers
o Optical Society of America
o Society of Fire Protection Engineers
o Society of Women Engineers

Associate Societies

o American Council of Independent Laboratory
o Federation of Materials Societies
o National Action Council for Minorities in Engineering
o Operations Research Society of America

Regional Societies

o Engineering Societies of New England
o Engineering Societies of Detroit
o Engineering Societies of Tulsa
o Engineers' Societies of Western Pennsylvania
o Western Society of Engineers

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Information Policy
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Legislative Report
National Government Activities
State Government Activities
Technology Policy Conference
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U.S. Competitiveness

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Career Activities Council
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April 5, 1991

The Honorable Rick Boucher
Chairman
Subcommittee on Science
House Science, Space &
Technology Committee
Washington, DC 20515

Dear Mr. Chairman:

The development and application of technology are particular interests of the Institute of Electrical and Electronics Engineers - United States Activities (IEEE-USA). We are the world's largest technical professional society with nearly a quarter of a million members in the United States engaged in advancing the frontiers of knowledge and sustaining our technological competitiveness with a broad and growing range of electrotechnologies. This gives IEEE-USA a special interest in U.S. government programs which support science and engineering research and education. We are therefore pleased to outline our views on the Administration's FY 1992 budget request for the National Science Foundation.

The IEEE-USA is concerned that a steady decline has taken place during the past thirty years in the secure positions of superior technological competitiveness and world industrial leadership once enjoyed by the U.S. There is a growing national consensus that, while the U.S. continues to lead the world in scientific discovery, we fail to gain the economic benefits that come from turning discoveries into technology and thus into production. All too often the results of American research are packaged and sold back to us by our international competitors because we lack the manufacturing technology to compete.

Accordingly, the IEEE-USA wishes to go on record as emphasizing the need for additional investment in engineering and technology. Engineering is, after all, the application of scientific principles to solve problems. While we are faced with significant social and economic challenges, we must recognize that technology is the solution to many of our national needs. Investment in engineering research and development will provide the economic growth, create new jobs, and generate the tax revenue necessary to satisfy our unmet social needs. We applaud the strong national support of science which has resulted in global leadership. But we urge an appropriate level of funding for engineering and technology so that the U.S. economy can harvest the fruits of these scientific breakthroughs.

U.S. national competitiveness in technology will require strengthening of a number of critical factors. The NSF can provide strong support for three of these: basic proficiency in mathematics and science required for a technically literate workforce, improved college curricula in technical areas, particularly engineering sciences, and the creation of centers for technological innovation where academia and industry together transition creative work from the laboratory to the marketplace. Each of these areas requires greater support from the Federal government, through the NSF.

For that reason, the IEEE-USA endorses the Administration's plan to double the NSF budget by FY 1994 and supports the FY 1992 budget request of $2.722 billion which would place NSF back on the doubling track.

In the past four fiscal years, NSF has had strong support from both the Administration and the congressional authorizing committees for the doubling goal as an important investment in the nation's competitiveness base. Each year, however, congressional appropriations have fallen considerably short of the doubling mark. Moreover, despite real increases in the overall NSF budget, many specific programs remain at or below their real FY 1988 levels when adjusted for inflation. The Coalition for National Science Funding has noted that the FY 1991 appropriation left nearly half (41 of 84) of the programs in four of NSF's research directorates at or below their FY 1988 levels when adjusted for inflation. Within the Engineering Directorate, approximately two-thirds (13 of 20) of the Directorate's programs are at or below FY 1988 levels.

With regard to specific NSF programs, the IEEE-USA strongly supports engineering science and research programs within the Engineering Directorate and the Computer and Information Science and Engineering Directorate. Although encouraged by the proposed 14.8 percent increase for the Engineering Directorate, we remained concerned that investment in specific programs such as the Engineering Research Centers would remain at or below FY 1988 levels when adjusted for inflation.

Particularly disturbing is the fact that the Engineering Directorate has been given no role to date in two key NSF initiatives. With respect to the high-performance computing initiative, no funding is proposed for the Engineering Directorate which supports important electronic device research and engineering science related to the initiative. Similarly, no funding is proposed for the Engineering Directorate with regard to the global climate change initiative despite that Directorate's responsibility for remote sensing, electric power systems, and sensor development.

We are also encouraged by the proposed 23.3 percent increase for Computer and Information Science and Engineering to a total of $229.5 million. We note, however, that $208 million of this total is dedicated to the Administration's High Performance Computing and Communications (HPCC) Initiative. We support the HPCC Initiative. However, we note that increases for HPCC come at the expense of increases for other important programs such as the NSF science and technology centers.

Finally, the IEEE-USA supports NSF's education and human resources programs. There will be a continuing demand for highly qualified scientists and engineers to conduct the research and development which is essential for continued technological competitiveness. Moreover, the U.S. must have a technically literate workforce to compete effectively in an increasingly complex and technologically driven global society. Therefore, we applaud a focus on K-12 math and science education as a vital investment in the nation's future.

We thank you for this opportunity to share our views on NSF's FY 1992 budget request. The IEEE-USA and its Engineering R&D Policy Committee stand ready to assist you as a resource for technical advice and policy perspectives on the NSF's critical science and technology programs.

Sincerely,

M.J. Whitelaw

Michael J. Whitelaw
Vice President
Professional Activities

and

Chairman
U.S. Activities Board

APPENDIX VI

Quality Science and Mathematics Education: A Multidisciplinary Approach

Project Director:
W. Tony Heiting
State Science Consultant
Iowa Department of Education
Grimes State Office Building
Des Moines, Iowa 50319

OFFICE OF THE GOVERNOR
STATE CAPITOL
DES MOINES, IOWA 50319
515 281-5211

TERRY E. BRANSTAD
GOVERNOR

October 12, 1990

Mr. Charles R. Eilber
Program Director
Statewide Systemic Initiatives - Room 504
National Science Foundation
1800 G. Street NW
Washington, DC 20550

Dear Mr. Eilber,

On behalf of the state of Iowa it is my pleasure to submit a formal application to the National Science Foundation in response to the Program Solicitation on Statewide Systemic Initiatives in Science, Mathematics, and Engineering Education.

As the 1989-90 Chairman of the National Governors' Association, I worked with President Bush and the nation's governors to develop national education goals, including the goal to make U.S. students first in the World in Mathematics and Science Achievement. It is my hope that the state of Iowa can help our nation accomplish those goals. Recently, I announced several new education initiatives, including a proposal to provide additional state funds to improve performance in mathematics and science. While we are just beginning to prepare the state budget for the next fiscal year, I intend to recommend an annual appropriation of $1 million for the purpose of providing matching funds for the grant we seek from the National Science Foundation. The state of Iowa will also seek an additional $1 million in private contributions for this purpose.

For the past several months, the Iowa Department of Education, representatives of public and private higher education institutions in Iowa, and an advisory group of educators and citizens have worked to prepare this proposal. I have designated the Iowa Department of Education as the agency responsible for administering this project. Dr. Tony Heiting, State Science Consultant, will serve as the Project Director.

Thank you for the opportunity to submit this application. I look forward to your favorable consideration.

Sincerely,

Terry E Branstad

Terry E. Branstad
Governor

STATE OF
IOWA

TERRY E. BRANSTAD, GOVERNOR

DEPARTMENT OF EDUCATION
WILLIAM L. LEPLEY, ED.D., DIRECTOR

October 11, 1990

Mr. Charles R. Eilber
Program Director
Statewide Systemic Initiatives Room 504
National Science Foundation
1800 G Street NW
Washington, D.C. 20550

Dear Mr. Eilber:

The state of Iowa welcomes this opportunity to respond to the National Science Foundation's (NSF) program solicitation for statewide systemic initiatives to improve math and science. We know that we have a strong need in Iowa to improve math and science education for the ultimate purpose of increasing student learning and to better prepare our students for their roles in the 21st century. The reforms proposed for the K-8 system in Iowa will lay the necessary foundation for the later involvement of our youth in grades 9-12 and into postsecondary education and/or a career in science and mathematics.

The Department of Education has identified a results-driven system as its major goal and the State Board of Education supports a multidisciplinary curriculum framework in its efforts toward school transformation. This initiative fits well with our Department of Education plan, and our program consultants are willing to commit their time and energy towards achieving the goals and objectives as outlined in this proposal.

As the Director of the Department of Education, I look forward to being the representative of the agency that will administer this grant. I am willing to commit the time of our state math and science consultants to administer this statewide initiative. I also anticipate that many other personnel in the Department will be directly involved as well in the implementation, because of the multidisciplinary thrust of this initiative.

I want to assure the support and participation of the Iowa Department of Education in the administration and implementation of Iowa's statewide systemic initiative to improve math and science as outlined in this proposal.

Sincerely,

William Lepley

William L. Lepley, Ed.D.
Director

COVER SHEET FOR PROPOSALS TO THE NATIONAL SCIENCE FOUNDATION

FOR CONSIDERATION BY NSF ORGANIZATIONAL UNIT (Indicate the most specific unit known, i.e. program, division, etc.) "EHR/TPE Statewide Systemic Initiatives Program"	PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE "Statewide Systemic Initiatives, NSF 90-47, October 15, 1990"

SUBMITTING INSTITUTION CODE (If known) 426004525	FOR RENEWAL ☐ CONTINUING AWARD ☐ ACCOMPLISHMENT BASED RENEWAL ☐ REQUEST, LIST PREVIOUS AWARD NO.:	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? Yes___ No. X IF YES, LIST ACRONYM(S)

NAME OF SUBMITTING ORGANIZATION TO WHICH AWARD SHOULD BE MADE (INCLUDE BRANCH/CAMPUS/OTHER COMPONENTS)
IOWA DEPARTMENT OF EDUCATION

ADDRESS OF ORGANIZATION (INCLUDE ZIP CODE)
Grimes State Office Building Des Moines, IA 50319-0146

IS SUBMITTING ORGANIZATION: ☐ For-Profit Organization, ☐ Small Business, ☐ Minority Business, ☐ Woman-Owned Business

TITLE OF PROPOSED PROJECT
Quality Science and Mathematics Education: A Multidisciplinary Approach

REQUESTED AMOUNT	PROPOSED DURATION	DESIRED STARTING DATE
14,161,682	September, 1991-September'96	September 1, 1991

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

- ☐ Animal Welfare
- ☐ Endangered Species
- ☐ Human Subjects
- ☐ Marine Mammal Protection
- ☐ Pollution Control
- ☐ National Environmental Policy Act
- ☐ Research Involving Recombinant DNA Molecules
- ☐ Historical Sites
- ☒ Interdisciplinary
- ☐ International Cooperative Activity
- ☐ Research Opportunity Award
- ☐ Facilitation Award for Handicapped
- ☐ Proprietary and Privileged Information

PI/PD DEPARTMENT	PI/PD ORGANIZATION	PI/PD PHONE NO & ELECTRONIC MAIL
Iowa Department of Education	Bureau of Instruction and Curriculum	515/281-3249 FAX - 515/281-6025

PI/PD NAME/TITLE	SOCIAL SECURITY NO*	HIGHEST DEGREE & YEAR	SIGNATURE
W. Tony Heiting, State Science Cons.	473-48-9812	Ph.D. - 1976	
ADDITIONAL PI/PD (TYPED)			
ADDITIONAL PI/PD (TYPED)			
ADDITIONAL PI/PD (TYPED)			
ADDITIONAL PI/PD (TYPED)			

For NSF Use

TO BE COMPLETED BY THE AUTHORIZED ORGANIZATIONAL REPRESENTATIVE By signing and submitting this proposal, the prospective grantee is providing the certifications set forth in (1) *Grants for Research and Education in Science and Engineering*, NSF 83-57 (rev. 11/87), and (2) Appendix C, 45CFR 620, Subpart F (Requirements for a Drug-Free Workplace).

(If answering yes to either, please provide explanation.)	YES	NO
Is the organization delinquent on any Federal Debt?		X
Is the organization presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency?		X

AUTHORIZED ORGANIZATIONAL REP	SIGNATURE	DATE	TELEPHONE NO
NAME/TITLE (TYPED) William L. Lepley, Ed.D., Director	Wm L Lepley		515/281-5294
OTHER ENDORSEMENT (optional)			
NAME/TITLE (TYPED)			

*Submission of social security numbers is voluntary and will not affect the organization's eligibility for an award. However, they are an integral part of the NSF information system and assist in processing the proposal. SSN solicited under NSF Act of 1950, as amended.

NSF Form 1207 (3/89)

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Name of Project:
Quality Science and Mathematics Education: A Multidisciplinary Approach

Name of State: Iowa

Name of Project Director: Dr. W. Tony Heiting, State Science Consultant

Address: Iowa Department of Education
Grimes State Office Building
Des Moines, Iowa 50319 (515) 281-3249

PROJECT SUMMARY

There is an abundance of research that shows that science is intrinsically multidisciplinary and that science must be studied emphasizing its cross-disciplinary nature. However, neither conventional science nor math programs give students the opportunity to develop an appreciation of the multidisciplinary nature of science or to know the intellectual relationships among science, math, technology, and other academic disciplines.

Iowa proposes to develop and implement multidisciplinary K-8 science curricula and make the necessary changes in our teacher preparation programs, standards, certification requirements, and staff development programs to facilitate the use of such "model" curricula in our schools.

This project will involve the development of a curriculum framework that provides direction for integrating the sciences around clearly recognized themes and includes the relationships of science to other disciplines, particularly those taught by K-8 teachers. Models will be identified which support the multidisciplinary approach from which teaching modules will be developed as examples of ways to integrate the sciences with each other and with other disciplines. The K-8 teachers will use this curricula framework to develop teaching modules that meet their specific needs in the classroom. Multidisciplinary science curricula will be initially piloted in "model classrooms" in school districts in each of Iowa's fifteen Area Education Agencies (AEAs).

PROJECT DESCRIPTION

INTRODUCTION

"Iowa, A Place to Grow." As you approach the borders coming into the state of Iowa, you are greeted by billboards with this motto. One of the main reasons Iowa is a "place to grow" is because Iowa prides itself on its educational system. Historically, Iowa has been a leader in education in the nation, a fact demonstrated by the high ranking of Iowa students on standardized assessment instruments, including the ACT and SAT exams. Iowans believe that excellence in education will enhance the quality of all citizens' lives, increase the productivity of the work force, and build citizen pride in the state. Iowa has three outstanding state universities (University of Northern Iowa, the University of Iowa, and Iowa State University) and 27 private colleges and universities with faculty who are national leaders in science and mathematics education. In addition, every K-12 school in Iowa is served by an Area Education Agency (AEA) which provides support for curriculum and staff development. The Iowa Department of Education is providing state leadership through developing new standards and policies for Iowa schools, focusing on initiatives which are designed to provide a world class education system and striving to meet the national education goals. Iowa's legislature is committed to the continual improvement of math and science education by making annual appropriations, and Governor Terry E. Branstad, in reference to this NSF solicitation has stated, "The Department of Education, with the assistance of higher education institutions, science and math teachers, and other interested Iowans is currently preparing a proposal for improving the quality of math and science education in Iowa. I intend to provide whatever support I can for their recommendations." Iowa has conducted over 100 research projects at its institutions in math and science education the past five years. Iowa sees this NSF solicitation as an opportunity to draw these positive efforts together into a systemic plan which will improve science and math education throughout the state.

The attributes above are not mentioned to boast Iowa's image, as Iowa faces the same critical and urgent needs to improve the education of its students in math and science education as do the other states. The attributes are mentioned, however, to assure the National Science

Foundation that Iowa has in place the structure, the expertise, the experience, and the sincere desire to implement the proposal outlined below, and to offer it as a model for other states.

I. STATEMENT OF THE RESULTS OF AN ASSESSMENT OF THE ESSENTIAL COMPONENTS OF THE SYSTEM OF SCIENCE AND MATH EXISTING IN THE STATE.

In Iowa, science and mathematics education is taught as prescribed by the laws and rules governing schools and school districts as set by the Department of Education (DE) and Iowa legislature. The 1984 FIRST IN THE NATION IN EDUCATION (FINE) study represented the beginning of an examination of new ways to improve education across the state. The study led to the development of the NEW STANDARDS FOR IOWA SCHOOLS: GUIDELINES FOR INTERPRETATION, completed in 1988 (see Appendix A). It provides specific guidelines encompassing general standards, administration, school personnel, and staff development. Iowa schools are required to undergo a two phase accreditation process in order to ensure compliance with the state standards. The accredition process consists of an annual report of compliance, and on-site visits by an Iowa Department of Education (DE) appointed committee.

In 1985, the Iowa legislature mandated that the DE develop subject matter committees. The committees devoted their first year of activity to the vertical articulation of each subject area. The curriculum guides developed in science and mathematics provided educators with philosophy, scope and sequence, and evaluation components. Included are lists of content areas and process skills by grade. Educators are expected to develop K-12 district "student outcomes" for the subjects based on these models. As of October 1, 1988, Iowa's teaching certification requirements require science and math endorsements for those teaching these subjects outside a self-contained classroom.

Iowa students have traditionally scored well on the various standardized assessment tools given in grades K-12, including the ACT and SAT college entrance exams. However, a close examination of the enrollment patterns of students in Iowa's high schools and colleges indicates that the numbers of students enrolling in upper level math classes in high school, in academic programs leading to science, math and engineering degrees, and the number of students choosing to enter math and science teaching fields is not meeting the identified need for such training. For example, in the 1988-89 school year, only 2,500 Iowa secondary students enrolled in calculus classes compared to approximately 20,000 in advanced algebra. Likewise, while over 18,000 students enrolled in chemistry classes, only 9,500 enrolled in physics.

When enrollment figures are examined by sex, secondary programs in math and science appear to be fairly balanced. However, the statistics at the post-secondary level show that female students are not choosing to enter the math, science and engineering fields. For example, in 1988, less than 25% of the degrees awarded in chemistry at the University of Iowa were awarded to female students. At Iowa State University, less than 10% of all engineering degrees were awarded to females in that same year, while at several peer institutions that figure was 17%.

Because Iowa is a state with only about 2% minority populations, all minority enrollment figures at the college level are low. Recognizing that cultural diversity is desirable, Iowa's universities have established recruitment goals to increase the percentage of minority students in all programs. Scholarships have been established to encourage minorities to enter science and math areas. At this time, it is premature to analyze the success of those programs.

Iowa's universities, like those of many other states, also provide science, math and engineering education, both undergraduate and graduate, to students from other nations. In many graduate programs, international students comprise as much as 50% of the total enrollment. Since most of these students return to their home countries, the actual numbers of students trained for America's work force is much less than it would appear to be.

The analysis of the data leads to the following conclusion: If Iowa is to achieve the goal of developing a highly skilled work force, with high number of students well prepared in math and science at both the secondary and postsecondary levels, then the place to begin such an effort is in the K-8 part of the educational system.

Few elementary school teachers have even a rudimentary education in science and mathematics, and many junior high teachers do not meet reasonable standards of preparation in those fields. These deficiencies have long been tolerated by the institutions that prepare teachers, the public bodies that license them, the schools that hire them, and even the teaching profession itself. Iowa's proposal focuses on what the state believes is needed to remove the educational deficiencies - a K-8 curriculum that integrates the sciences and other academic disciplines, and focuses on clearly defined student outcomes, followed by the necessary changes in our teacher preparation programs, certification requirements and standards, and a broadening of the support base to ensure assessment information and a system for promoting continued improvement.

Succintly stated, these are the needs identified in assessing the status of math and science education in Iowa:

NEEDS IN IOWA TO BE MET

- *Change from the traditional fact-oriented science curriculum/courses/textbook approach to one characterized as multidisciplinary and one that is seen as more relevant and useful in the lives of students.*
- *Enhance teacher competence and enrichment in math and science education.*
- *Develop student achievement outcomes in math and science and appropriate assessment methods to measure these outcomes.*
- *Revise Iowa school standards to support a multidisciplinary approach that reflects research findings concerning instruction and learning in science and math education.*
- *Upgraded requirements and research-based objectives in teacher certification in math and science.*
- *Change teacher preparation programs in math and science to make them consistent with the goals, curricular framework, and teaching strategies necessary for the improvement efforts envisioned.*

While the standards and certification requirements have been revised to improve science and math education in the state, they still reflect a traditional approach to teaching science and math. Change will be necessary to facilitate the development and implementation of a K-8 multidisciplinary science curriculum as outlined in the remaining sections of this proposal.

II. DESCRIPTION OF THE ELEMENTS - COMPONENTS AND ESSENTIAL THRUSTS

This proposal will not dwell on the urgent need to improve science and mathematics education. Most of the education reports of the 1980's have adequately addressed our country's overall concerns: low test scores; students' avoidance of mathematics and science; a weakening teaching staff in many schools; the low number of females and minorities; low learning expectations compared to other advanced nations; a scientifically illiterate society; and being ranked near the bottom in international studies on students' knowledge of science and mathematics.

Much has been written about the inadequacy of science curriculum as it has been and is being taught today. Paul DeHart Hurd states that the aims of traditional science education, the choice of subject matter, the context of the curriculum, and modes of instruction are now viewed as historically bound and too narrow in concept to provide an understanding either of modern science and technology in our culture (Hurd, Paul, 1984). Voelker says, "we cannot assume that curricula which emphasizes traditional cognitive knowledge and an understanding of the scientific process will lead to an understanding of the science-related issues confronting society. Neither can we assume that the traditional curricula will assist our student-citizens in applying their scientific knowledge and processes to these issues" (Voelker, A.M., 1982).

Iowa's proposal is based on the premise that the K-8 science curriculum and teaching must provide the student with a conceptual framework that aids in understanding the natural world, shows the relationship of scientific phenomena to other disciplines and their field of knowledge, applies scientific knowledge to reach human decisions, and sustains an interest in science as a life-learning process and career opportunity for both males and females. The traditional science curriculum and teaching have done a poor job in accomplishing this premise. Science is intrinsically multidisciplinary and students know only a multidisciplinary world! So why have we not developed and implemented a science curriculum with a multidisciplinary focus - one which integrates the relationships of the scientific disciplines as well as the relationships of the sciences to other disciplines? This is exactly what Iowa proposes to do in its statewide systemic proposal to improve K-8 science and mathematics education.

The development of Iowa's K-8 multidisciplinary science curricula will necessitate changes, to remove problems or obstacles to ensuring the proper implementation of the curricula and systemic improvements across the state. Problems which must be faced: 1) Time and resources needed to prepare a multidisciplinary curricular framework and teaching modules; 2) There is a lack of competent teachers to use model multidisciplinary curricula in grades K-8; 3) It will take time, resources, and cooperation to change teacher preparation programs in science and math education at our colleges and universities; 4) Certification requirements for the teaching of science and math will need to be revised and enacted; 5) Extensive statewide staff development of science and math teachers will require cooperation of administrators, new resources, and significant costs; 6) Changes will be needed in Iowa state standards to include time allocations and results and outcomes for teaching science. Iowa's plans for reducing or removing these obstacles is explained in the specific activities in this initiative.

Below are the goals and objectives Iowa's statewide initiative will address and the outcomes we expect:

GOALS

- *Increase scientific literacy for K-8 students in Iowa and to impact all people in the state.*
- *Increase the number of students in Iowa who choose science, engineering or science/math education as careers.*
- *Increase student achievement scores in math and science in Iowa, while also broadening the scope of assessment.*
- *Increase the number of students in Iowa who retain enthusiasm and interest in science and math into and beyond the K-8 level.*

OBJECTIVES

- *To develop a model for multidisciplinary science curricula that will serve as the framework for the development of individual teaching modules.*
- *To design and implement a statewide model for staff development in science and math education.*
- *To establish specific recommendations and rationale for changes in Iowa school standards that will facilitate improvements in math and science education and provide outcomes that serve as a standard of successful learning.*
- *To develop and recommend specific changes in the requirements for the certification of teachers in math and science.*
- *To provide a sequence of competencies and instructional strategies to be included in a refined teacher preparation program for those entering math and science in all Iowa teacher preparation institutions.*
- *To develop and implement a new statewide assessment program that is consistent with the materials and approaches envisioned.*
- *To develop and implement both proven and new strategies to recruit and retain females and minorities in math and science-related education areas.*

EXPECTED RESULTS/OUTCOMES

- *Statewide adoption of the multidisciplinary science curriculum model and implementation in all Iowa school districts.*
- *Staff development inservice and training in the multidisciplinary science approach for all of Iowa's 16,000 K-8 science and mathematics teachers.*
- *Changes in Iowa School Standards congruent with the multidisciplinary approach to improve instruction and student learning in math and science.*

- *Changes in teacher certification requirements that are congruent with the multidisciplinary approach in science and mathematics.*
- *Adoption of a model teacher preparation program for Iowa's teacher education institutions that is consistent with the curricular framework and teaching strategies developed and implemented in this initiative..*

ACTIVITIES

MULTIDISCIPLINARY SCIENCE CURRICULA (MSC)

The following diagram represents the sequence of events that will take place in developing the Multidisciplinary Science Curricula (MSC).

DESIGN of: curricular framework—→BUILT on: multidisclipinary approach of integrating the sciences, and the sciences with other academic disciplines

→IDENTIFICATION of: MSC models such as those proposed in Project 2061, STS →DEVELOPMENT of: sample MSC teaching modules

—→METHODS and INSTRUMENTS for: evaluation of student outcomes

The first step in developing of multidisciplinary science curricula (MSC) in this initiative will be the design of a model based on appropriate learning theory. This will be done by educators involved in this initiative who have extensive expertise and experience in science and math education and additional qualified educators representing the other academic disciplines. Research in learning has been extremely fruitful over the past decade (Reilly, 1989). Learning theories such as Piagetian cognitive psychology and the constructivist learning model will be considered. The MSC will integrate the sciences and other academic disciplines. The model will provide the framework for the development of MSC teaching modules. A model for evaluating student outcomes will also be identified.

Key teachers at the K-8 levels will be selected to participate in a four week summer "Multidisciplinary Development Institute." This will occur in the summer of the first year of the initiative. The institute will be conducted by a college or university and involve "lead teachers" who have experimented with multidisciplinary approaches in their classrooms. The objective of the institute is to develop MSC teaching modules that will serve as examples for teachers and schools in integrating the sciences with each other and with other disciplines being taught at the K-8 grades in Iowa.

To achieve the desired integration, clearly recognized themes will be identified to serve as the central core in the developing the modules. Consideration will be given to themes identified in Project 2061, STS, and by others (Moore). The themes that are identified will be carried through each grade (K-8) with advancing conceptual levels. An example of three themes that have relevance to different disciplines is given in the diagram in Figure 1. Using these three themes - Space, Inventions, and Living Things, example activities are presented that show how to teach science concepts in other disciplines and within the sciences, (see Appendix B). From these activities, teaching modules can be developed which meet the specific needs of the teachers and students. The teaching modules would include goals and objectives, materials needed, time allocated, and expected student outcomes and results.

Many themes and topics may be drawn from the information and projects mentioned above (e.g., Project 2061). Criteria that will be considered in selecting and designing themes will include the following:

- They build upon students' prior experiences and knowledge.
- They capture students' interest.
- They are engaging, interactive, and experiential.
- They are interdisciplinary, so that students see that reading, writing, mathematics, social studies, and other curricular areas are part of science.
- They integrate several science disciplines.
- They are vehicles for teaching major organizing concepts, attitudes, and skills.

At the elementary level, the modules will emphasize a hands-on approach, with opportunities for children to do things for themselves - inquire, observe, discover, manipulate, test

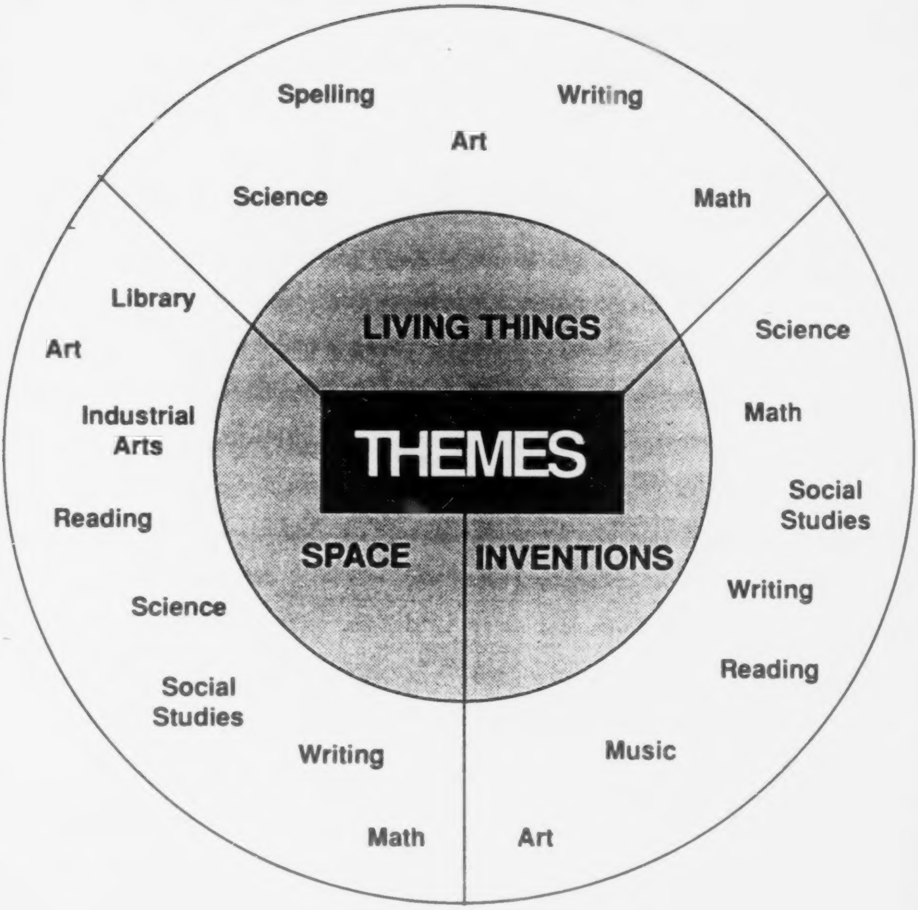
Spelling
Writing
Art
Science
Math
LIVING THINGS
Library
Art
Industrial Arts
Reading
Science
Social Studies
Writing
Math
THEMES
SPACE
INVENTIONS
Science
Math
Social Studies
Writing
Reading
Music
Art

Figure 1

hypotheses, and reach conclusions. At the middle school level (grades 7,8), the modules will continue the various sorts of explorations built around themes emphasized at the K-6 level, but with more of a focus on the students themselves and their interest in societal issues. Also, at the middle school grades, there will be some focus on science as disciplines (which will be a consideration in grades 9-12, as for example, in the NSTA Scope and Sequence Project). Assessment instruments that measure student outcomes will be an integral part of the MSC.

The MSC will be pilot tested the following fall by schools in each of Iowa's Area Education Agencies (AEA's). These schools will serve as "model classrooms" in the beginning of the implementation process. Commitments of support from the schools, school district, and cooperating teachers have already been initiated. The pilot test teachers and schools will be provided the needed supplies, facilities, and resources identified at the summer institute to assure the successful completion of the pilot tests. In addition, pilot schools will participate in the Gender/Ethnic Expectation and Student Achievement (GESA) program to learn strategies designed to recruit and retain females and minorities in science and math. At least 30 schools will be involved in the initial pilot testing which will conclude at the end of the regular school year. An assessment and evaluation of the pilot test will be made in a two week summer workshop involving the teachers from the pilot schools, and coordinated by the same college/university that conducted the summer institute. Revisions in the MSC based on the results of the evaluation will be made at this workshop.

The state of Iowa has 15 geographically dispersed Area Education Agencies (AEAs) (see Appendix C). Each of the AEA's has a math/science coordinator. These coordinators serve as resources for the 431 school districts in the state, and will be key facilitators in curriculum and staff development during the course of this initiative. During the first year of pilot testing, the AEA science/math coordinators will be inserviced. (It is noted that all AEA science/math coordinators have had the opportunity for input into this initiative as part of the PSInet network). The objective of the AEA inservice is to familiarize the coordinators with the MSC and the pilot testing. The 15 AEA coordinators will then conduct inservice workshops for administrators and teachers in the school districts they serve, to introduce the goals, objectives, and activities of Iowa's statewide systemic initiative in improving math and science education. The ultimate outcome of these workshops is to identify schools/school districts that have the interest and capabilities to serve as pilot test sites the following school year (and succeeding years) for implementing MSC. A one-week workshop will be conducted by each AEA the following summer for those teachers who will participate the following fall in the pilot test. This workshop will provide instruction on content and teaching strategies needed for implementing the MSC. The GESA training component will also be provided for all participating schools.

The format of inservices for administrators and teachers mentioned above will continue by the AEAs in the third, fourth, and fifth years of this initiative and beyond if necessary. In the sixth year, a multidisciplinary science curriculum will be adopted as the state guide for teaching science at the K-8 levels in Iowa. Inservicing and staff development will continue until all 431 school districts have implemented MSC. All the activities mentioned above will be coordinated by a full time MSC coordinator hired by the institution responsible for the development and implementation of the MSC.

STAFF DEVELOPMENT

In Iowa, as in many other states, there are teachers teaching science who do not have a science endorsement and/or the necessary qualifications. This situation is more apparent at the elementary level where teachers are expected to teach science with little or no content background. The implementation of MSC as the science curriculum model for the state will require a general content background in the sciences. Teacher background information and resources will be a part of the MSC. MSC will be developed as a "user friendly" science curriculum, one which the K-8 teachers and students will not feel intimidated by, but comfortable with. However, this does not preclude the fact that teachers will need enrichment courses in science content, process, and teaching strategies to competently implement the MSC in their classrooms as the materials and strategies require. The specifics of the staff development training will be determined as the MSC is developed.

In the first year of this initiative, an invitation will be sent to Iowa's public and private colleges and universities and community colleges as well as other educational institutions (such as AEAs) inviting their participation in a model staff development and training program for adapting the MSC into classrooms and schools. Once the staff development and training model has been developed, the institution selected for this task will arrange for staff development workshops throughout the state for the duration of this NSF initiative and in subsequent years until all Iowa K-8 teachers have been inserviced with the MSC model.

The coordinating institution will hire a full time staff development coordinator and identify the instructors for the staff development workshops. The instructors, will be teachers who have been involved in the development of the MSC, the pilot tests, and those previously inserviced in staff development. These staff development workshops will offer graduate credit and a stipend for all participating teachers. Inservice courses will be required which focus on content related to the various MSC materials and the teaching strategies needed to use them properly. The staff development workshops will be offered throughout the year at Iowa's 15 community colleges and 5 branches.

To expedite the inservicing of a large number of teachers, Iowa will make use of its satellite telecommunications network. Iowa has three "uplink" satellites (located at the University of Iowa, Iowa City, Iowa State University, Ames, and Iowa Public Television Network, Des Moines) and 90 "downlink" satellite receiving stations, one in every county of Iowa. These will serve as sites for teachers to come for the inservices. The downlink sites allow a one way visual, two-way audio communication link. A teacher should not have to travel over 20 miles to attend a staff development inservice if all the telecommunication sites and community colleges are used (see Appendix D - maps of community colleges and telecommunication locations). Utilizing Iowa's community colleges, telecommunications network, and AEAs, it is estimated that over 12,000 math and science teachers will participate in MSC staff development inservices. In addition to utilizing the community colleges and telecommunications for staff development, the coordinating institution will produce a video tape of an MSC staff development inservice and make it available for dissemination to schools and school districts for staff development purposes. This will accommodate the staff development of not only teachers trained and certified in Iowa, but also those who come to Iowa to teach from other states.

The coordinating institution will conduct "Training of Trainers" workshop(s) for the approximately 30 designated participants who will be staff development instructors (one for each community college, one or more for each of the three uplink sites). Extensive staff development training for K-8 math and science teachers will begin in the third year of this initiative. This will allow time in the first and second year to evaluate the MSC, the pilot testing, and make the necessary revisions. These staff development inservices will go on concurrently with those being conducted by the AEAs for selected schools or school districts that are involved in the pilot testing.

Staff development of Iowa's K-8 science and math teachers will be a costly venture, but a necessary one if we are to make significant improvements in science and mathematics education in the state. There are 14,000 K-6 teachers in Iowa and approximately 2,000 math and science teachers in grades seven and eight. The staff development will continue beyond the duration of NSF funding.

IOWA SCHOOL STANDARDS

As Iowa schools look toward school transformation, they are looking beyond the present "process standards", requiring that certain topics be addressed, to more focus upon student learning results. What do students actually know and what can they do as a result of the educational process? Focusing on these questions will drastically change how Iowa does the business of schooling and learning. Presently, people assume that because students spend a certain amount of time studying science and math, and have passed a paper and pencil test on the content taught, they really understand and can apply their learnings. In the future in Iowa, schools will be held accountable for their students' demonstrated learning. In order to do this several things need to occur:

1. Outcomes will be developed that serve as a measure of successful learning. Broad-based input will be sought from math and science and other disciplines across the state in order to develop comprehensive outcomes.
2. Assessments of these outcomes will need to be developed that will measure the competency and performance level achieved. Many alternative assessment strategies will be developed which can document individual progress over time. Assessment experts from outside the state will also be involved as assessment reform is sought.
3. Rather than prescribe lists of specific life, earth and physical science concepts which must be learned at or by certain grade levels, or specify time allocations for science, it is proposed that the Iowa Standards be revised to reflect a multidisciplinary thrust. Themes similar to those proposed in the AAAS Project 2061 will replace the standards science lists and allow schools greater flexibility in restructuring their science curricula. Such a set of new state standards would provide parameters with a focus on "broad themes" in science rather than on fragmented concepts.

A committee will be formed to accomplish these tasks. Members of the committee will be drawn from the Iowa Council of State Science Supervisors, the Iowa Council of Teachers of Mathematics, (see Appendix E for listing of these two organizations), and representatives from colleges and universities, the Bureau of School Administration and Accreditation of the Iowa Department of Education. To assure representative input, selected teachers and administrators from across the state will also serve as members. The committee will focus on: 1) identifying present standards that affect the objectives of this initiative; 2) identifying those standards which present a barrier to improving math and science; 3) developing and revising standards to reflect the thrust of this initiative.

Other standards that will be addressed in relation to this initiative are: multicultural, nonsexist education, staffing policies, the use of educational aides, teacher preparation time, technology in the curriculum and global education, talented and gifted, at-risk students, guidance programs, school media, and staff development programs. Standards have been set for each of these areas. They are minimum standards, and ones that do not necessarily facilitate improvements in math and science education. We hope to focus on what is possible and what can be attained as opposed to minimal standards.

The committee will examine these standards, along with those specific to science and math, in relation to the goals and objectives of this initiative and with consideration of national standards that have been developed by the National Science Teachers Association, the American Association for the Advancement of Science, and the National Council of Teachers of Mathematics, among others, that will be used as models. The standards committee will present its findings in a report to the Iowa Department of Education with specific recommendations for change. The Department of Education will work with the Governor's office, the Iowa legislature, and the Iowa State Board of Education for adoption of new and revised standards.

TEACHER CERTIFICATION REQUIREMENTS

The Bureau of Teacher Education and Certification of the Iowa Department of Education has recently revised the requirements for obtaining a teaching certificate in mathematics and science teaching. While these changes were an improvement from those previously in place, further modifications will be necessary to ensure that the prospective math or science teacher has competencies and teaching skills to implement MSC.

Presently, an elementary teacher could be teaching science in a self-contained classroom with little or no science background. Prior certification requirements at the middle school level (grades 7, 8), allow a teacher with a general endorsement to also be teaching science or math with little content background in these disciplines. It follows that there are teachers in Iowa teaching science and/or math who lack optimum qualifications. The problem is even more acute because Iowa is an agricultural state with a dominance of rural areas and small towns that have trouble attracting qualified math and science teachers to their schools.

A committee has been formed to study, modify and refine present requirements and provide changes to be made in certification for teaching math and science at the K-8 levels. The committee includes representatives from the Bureau of Teacher Education and Certification, and the Iowa Board of Educational Examiners, representatives from Iowa's teacher preparation programs, as well as classroom teachers themselves.

The committee will submit a final report to the Iowa Department of Education in the fourth year of this initiative. It will be based upon evidence collected from three years of the effort outlined in this initiative. The committee will systematically review the evaluation and results of the MSC pilot test as well as the preliminary results of the staff development program. These results will help formulate recommendations for change in Iowa's certification requirements for prospective teachers of math and science.

TEACHER PREPARATION

As a nation, we are moving toward a definition of a professional teacher. In the process, we are developing professional standards boards nationally. In many states, schools are becoming more concerned with the professional teacher who understands subject matter, goals for teaching, and how their students learn. In addition, these professional teachers are concerned with the relationship of their subject to other subjects in the curriculum. Professional teachers also have confidence in themselves, their teaching, and their curriculum development, and are prepared and active in presenting their work to their colleagues. Often, they adapt other curriculum to fit the needs of their students (Good and Weinstein, 1986). It is precisely these teachers who are needed in Iowa for major reform involving multidisciplinary science at all levels.

While some teacher education programs approach the standards necessary for development of such professional teachers, the effort in Iowa and in other states is not uniform. To produce an effective science education program for our K-12 students, we must have effective teachers, and by necessity, effective teacher education programs.

In teacher education programs there are normally large discrepancies between the experiences that are optimum and those that preservice teachers actually have as part of the preparation program. These discrepancies are among the factors contributing to the current disenchantment with teacher education. The National Assessment data reveal a similar disenchantment with science itself in secondary school classrooms throughout the nation; there may well be a cause-effect relationship.

Programs must narrow the gap between goals and practice both in science teaching and in science teacher education. A science teacher education program promotes developing science curricula and teaching strategies more consistent with what is known about science, learning, teaching skills, and the community context in which the learning and teaching take place (see Berliner, 1984). More specifically, a professional science teacher education program must be prepared to provide students with significant experiences with the following topics and issues:

- multiple dimensions of science,
- computers and new technologies in teaching,
- local and personal relevance,
- science-related societal issues,
- sensitivities in motivation and learning,
- new conceptions of human behavior,
- learners who have vastly different interests, skills and abilities.

Most teacher education programs today were designed for an earlier era and a different reality. Science education must provide experiences that nurture the development of understanding appropriate for contemporary needs. We have examined the goals for introductory science education and have developed a program model in science teacher education responsive to these goals as well as to institutional realities.

To create such teacher education programs will require careful analysis of the needs of schools and teachers, new curriculum developments as a result of this proposal, and capabilities of various institutions. From examining teacher education programs nationally, we know that we must move in the direction of more intensive experience including extended field experiences prior to student teaching, more methods courses focusing on self-analysis, curriculum development and adaptation, and strategies of teaching which will encompass a multidisciplinary approach. Supervision of preservice teachers must be enhanced and teacher induction programs must be created. In addition, considerable inservice effort must be taken to insure that teachers currently in the work force teach a multidisciplinary science curriculum as it should be, reflecting both the nature of science and what we know about how our students learn.

There is a multitude of research literature on the characteristics of effective teachers and the determinants of effective teaching. Much of this research has been done at universities in Iowa. Considerable attention will be given to this research, including the Scope, Sequence, and Coordination Project at the University of Iowa, the NSF project at the University of Northern Iowa on the preparation of elementary school science and mathematics teachers and the model secondary program at the University of Iowa as we develop a teacher preparation program that will address the needs of this initiative and result in improvements in teaching.

The Iowa Department of Education will coordinate cooperation among all colleges and universities in Iowa to undertake a comprehensive review of our state teacher preparation programs. A coordinating institution will be selected and a full time teacher preparation coordinator hired. This project will commence in the second year of this initiative to allow consideration of the developing MSC, along with recommended changes in the Iowa school standards and certification requirements. Issues that the investigators will address are: 1) the subject matter content that should be required in math and science for K-8 teachers; 2) development of a repertoire of teaching strategies relevant to the implementation of the MSC; 3) course syllabus for the new teacher preparation program; 4) changes in the educational environment that need to be made to complement the changes in teachers and teaching being proposed.

Fragmentation of the teacher preparation programs at the 28 colleges and universities offering such training is a major problem, producing Iowa science and math teachers with varying degrees of expertise and teaching skills. Thus, one objective of this phase of the initiative will be to develop a "model" teacher preparation program that will characterize all teacher education programs in the state. With such preservice teacher education programs, we will be building for the future.

A final report will be presented for review and comment to the Iowa Board of Regents, the Iowa Association of Independent Colleges, and the Iowa Department of Education. Assuming approval by these bodies (with changes they may recommend), the model teacher preparation program will begin pilot testing the fall of the third year at a college or university selected by the Iowa Board of Regents. The model program will be evaluated at the end of the normal school year and revisions made based on the evaluation. Pilot testing will continue into the fifth year of this initiative and beyond with implementation of the model program in the other Iowa teacher preparation programs.

STUDENT OUTCOME AND ASSESSMENT GOALS

Tests are instruments used to determine a curriculum's effectiveness in stimulating learning. Conventional course assessment strategies are generally limited to the measurement of student's comprehension of scientific and mathematical facts and concepts. These tests alone cannot assess adequately the mastery of science or mathematics. Assessment should provide students with opportunities to demonstrate their accomplishments in a variety of ways.

The "Iowa Assessment Package for Evaluation in Five Domains of Science Education" will be a model for determining student outcomes from the MSC. The five domains in which evaluation of student outcomes will take place are:

Domain 1 - Knowing and Understanding (Concepts Domain)

Rationale: Part of any science instruction involves students' learning some of the concepts central to science and math. This understanding is important, particularly when students use what they have learned.

Domain 2 - Exploring and Discovery (Process Domain)

Rationale: There are specific and definable processes that characterize human actions that result in new knowledge of the universe such as those identified by AAAS in the development of Science: A Process Approach that can have applicability for all learners. To know the processes means being able to use them in a variety of situations.

Domain 3 - Using and Applying (Applications Domain)

Rationale: It seems pointless to have any science or math program if the program does not include some substantial amount of information, skills, and attitudes that can be transferred and used in students' everyday lives. Students need to become sensitized to those experiences they encounter which reflect ideas they have learned in school science and math.

Domain 4 - Imagining and Creating (Creativity Domain)

Rationale: Scientists themselves apply creative solutions to real problems. Therefore, it is reasonable to encourage the development and expansion of students' creative abilities.

Domain 5 - Feeling and Valuing (Attitudes Domain)

Rationale: All learning is enhanced when students have a positive attitude. They are more motivated, more involved with meeting course objectives, more likely to realize instructional goals.

A complete description of each domain is given in the document "THE IOWA ASSESSMENT PACKAGE FOR EVALUATION IN FIVE DOMAINS OF SCIENCE EDUCATION" in Appendix F .

WOMEN AND MINORITIES IN SCIENCE

As indicated by data provided in section I, Iowa recognizes the need to more concretely address the movement of females and minorities into the pipeline leading to careers in math, science and engineering. During the past four years, Iowa State University has developed a model Women in Science and Engineering Program. Although this program was initially developed to recruit more women into ISU's programs, it quickly became apparent that such recruitment required initiatives at every level of education, from K-3 through graduate school. This initiative proposes to replicate ISU's successful programs at both the University of Northern Iowa and the University of Iowa, and throughout the community college system, with an emphasis on both females and minorities.

Program components to be replicated include career conferences for girls in grades 6-12; teacher education programs to decrease gender and race disparity in the classroom at all levels; and the support system for women in nontraditional programs at the other two state universities and in the community college system. By creating awareness that math and science are critical to many occupational choices, long term evaluation should show that proportionately more females and minorities enter these programs than occurred in the past. In addition to the recruitment component, critical programs which provide support and retain women in nontraditional programs will be developed. The measure of success will be the ratio of entering to graduating female students in such programs.

The development of these programs now means that female and minority students who are provided the benefit of multidisciplinary K-8 science education, will find support systems in place for them when they reach the postsecondary level.

THE USE OF EDUCATIONAL TECHNOLOGY

State of Iowa Standard 12.5(10) requires school districts to infuse technology into the curriculum. Technology needs to be infused into curriculum not just because of this standard but because of the powerful impact it can have on instruction, especially math and science instruction. Not only is it appropriate for technology to be utilized in specific subject areas but it is extremely vital that technology be incorporated into a multidisciplinary curriculum. Frequently schools lack the resources to purchase these tools and to some degree lack the training necessary to utilize technology effectively. In many cases, assistance is needed to match available and appropriate technologies during curriculum development.

Technology considerations will be an essential and vital component of this project. Key areas where technology will be especially important include: cross-disciplinary, multidisciplinary curricula models, vertical articulation, student outcomes, curriculum based on themes, individual teaching models, staff development, instructional strategies, teacher preparation, curriculum integration, retraining of teacher, and model teacher preparation program.

Technology will provide an important role in multidisciplinary curricula development. The following will be considered in this initiative: infusion of technology in the multidiscipinary curricula; assessment, infusion of technology for skills necessary in an information age; as well as technology's impact on the important skill areas of problem solving, communication, higher order thinking, reasoning, and learning to learn.

PROJECT ACTIVITY CALENDAR

YEAR 1: SEP 1, 1991 - AUG 31, 1992	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
GENERAL												
Agreements with senior personnel secured	XXX	XXX										
Hire project evaluator			XXX	XXX								
Hire partnership coordinator		XXX	XXX									
Conduct forums around state	XXX	XXX	XXX	XXX								
Advisory/oversight committee meeting	XXX					XXX						
Hire DE coordinator	XXX											
Secure commitments of support & time from AEAs	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Establish technology needs						XXX	XXX	XXX	XXX	XXX	XXX	XXX
Meeting of governing body												XXX
MULTIDISCIPLINARY SCIENCE CURRIC (MSC)												
Selection of coordinating institution	XXX	XXX										
Hire MSC coordinator		XXX	XXX									
Identify MSC lead teachers		XXX	XXX	XXX	XXX							
Design MSC framework		XXX	XXX	XXX	XXX	XXX	XXX	XXX				
Spring meeting with MSC lead teachers								XXX				
Summer MSC workshop for 60 lead teachers										XXX	XXX	
Identification/selection of "model classrooms"								XXX	XXX	XXX	XXX	
Training of pilot test teachers											XXX	XXX
AEA inservice for science/math supervisors							XXX					
STAFF DEVELOPMENT												
Selection of coordinating institute					XXX	XXX						
Hire staff development coordinator						XXX	XXX					
Develop model for staff development								XXX	XXX			
Negotiations with community colleges											XXX	XXX
Negotiations for satellite communications network											XXX	XXX
IOWA SCHOOL STANDARDS												
Formation of MSC school standards committee							XXX	XXX				
TEACHER CERTIFICATION REQUIREMENTS												
Form teacher certification committee					XXX							
Develop specific objectives								XXX				
Teacher certification committee meeting									XXX			
TEACHER PREPARATION												
Selection of coordinating institution			XXX									
YEAR 1: SEP 1, 1991 - AUG 31, 1992	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG

PROJECT ACTIVITY CALENDAR

YEAR 2: SEP 1, 1992 - AUG 31, 1993	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
GENERAL												
Project evaluation activities	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Agreements with senior personnel secured	XXX											
Partnership program implementation	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Advisory/oversight committee meeting	XXX						XXX					
Establish technology needs	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Secure legislative support				XXX	XXX	XXX	XXX	XXX	XXX			
Meetings of governing body	XXX					XXX						
MULTIDISCIPLINARY SCIENCE CURRIC (MSC)												
Pilot test of MSC in 15 AEAs	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Evaluation/revision MSC workshop - 2 weeks										XXX		
AEA workshops for administrators/teachers			XXX	XXX	XXX	XXX						
Identify pilot test teachers/schools							XXX	XXX				
AEA workshops for new pilot teachers - 1 week											XXX	
STAFF DEVELOPMENT												
Identify & select staff development instructors							XXX	XXX	XXX			
Training of trainers workshop - 2 weeks											XXX	XXX
Complete negotiations with community colleges	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Complete negotiations with satellite network	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Develop & distribute staff development brochures											XXX	XXX
IOWA SCHOOL STANDARDS												
Identify specific objectives for committee	XXX	XXX	XXX	XXX								
MSC school standards committee meeting					XXX					XXX		
TEACHER CERTIFICATION REQUIREMENTS												
Teacher certification committee meetings			XXX						XXX			
Develop draft report of recommended changes									XXX	XXX	XXX	XXX
Send to teacher preparation institutions												XXX
TEACHER PREPARATION												
Hire teacher preparation coordinator	XXX											
Form teacher preparation task committee		XXX	XXX									
Initial meeting of task committee				XXX								
Develop teacher preparation model					XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
YEAR 2: SEP 1, 1992 - AUG 31, 1993	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG

PROJECT ACTIVITY CALENDAR

YEAR 3: SEP 1, 1993 - AUG 31, 1994	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
GENERAL												
Agreements with senior personnel secured	XXX	XXX										
Project evaluation of activities	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Partnership program implementation	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Advisory/oversight committee meeting	XXX						XXX					
Establish technology needs	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Secure commitments from legislature/business	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Meetings of governing body	XXX					XXX						
MULTIDISCIPLINARY SCIENCE CURRIC (MSC)												
2nd pilot test of MSC in 15 AEAs	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
2nd evaluation/revision MSC workshop - 1 week										XXX		
AEA workshop for administrators/teachers			XXX	XXX	XXX	XXX						
Identify new pilot test schools/teachers/districts							XXX					
AEA workshops for new pilot teachers -1 week											XXX	
STAFF DEVELOPMENT												
Staff development & training workshops	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Trainer evaluation & revision workshop						XXX						XXX
Send out staff development brochures							XXX	XXX	XXX	XXX	XXX	
Identify & select additional training instructors							XXX					
Conduct training of trainers workshop - 2 weeks											XXX	XXX
IOWA SCHOOL STANDARDS												
MSC school standards committee meetings		XXX				XXX				XXX		
Develop draft recommendations for changes						XXX	XXX	XXX	XXX	XXX	XXX	XXX
TEACHER CERTIFICATION REQUIREMENTS												
Receive response from teacher prep institutions		XXX										
Teacher certification committee meetings		XXX						XXX				
Finalize report to Dept of Educ & Board of Regents											XXX	
TEACHER PREPARATION												
Teacher preparation task committee meetings	XXX			XXX				XXX				XXX
Submit draft rep on recommendations for change									XXX	XXX	XXX	
Changes/revisions to report												XXX
Select pilot test teacher preparation institution				XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
YEAR 3: SEP 1, 1993 - AUG 31, 1994	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG

PROJECT ACTIVITY CALENDAR

YEAR 4: SEP 1, 1994 - AUG 31, 1995	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
GENERAL												
Agreements with senior personnel secured	XXX											
Project evaluation of activities	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Partnership program implementation	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Advisory/oversight committee meeting	XXX						XXX					
Establish technology needs	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Secure commitments from legislature/business	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Meeting of governing body	XXX					XXX						
MULTIDISCIPLINARY SCIENCE CURRIC (MSC)												
3rd pilot test of MSC in 15 AEA's school districts	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
3rd evaluation/revision MSC workshop - 1 week										XXX		
AEA workshop for administrators/teachers - 15			XXX	XXX	XXX	XXX						
Identify new pilot school districts/teachers							XXX					
AEA workshop for new pilot teachers -1 week											XXX	
STAFF DEVELOPMENT												
Staff development & trainer workshops	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Trainer evaluation & revision workshop												XXX
Send out staff development brochures							XXX	XXX	XXX	XXX	XXX	XXX
Videotape production of staff development workshop	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
IOWA SCHOOL STANDARDS												
MSC school standards committee meetings	XXX			XXX				XXX				
Finalize recommendations for changes	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Submit to Iowa State Board of Education										XXX		
TEACHER CERTIFICATION REQUIREMENTS												
Response from Board of Regents & Dept of Educ		XXX										
Teacher certification committee meetings			XXX					XXX				
Plan to implement changes									XXX			
Implement plan												XXX
TEACHER PREPARATION												
Pilot testing of teacher preparation model	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Teacher preparation task committee meetings				XXX						XXX		
Revision/evaluation of pilot test											XXX	XXX
Select 3 more teacher prep institutions for pilot testing						XXX	XXX	XXX	XXX	XXX		
YEAR 4: SEP 1, 1994 - AUG 31, 1995	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG

PROJECT ACTIVITY CALENDAR

YEAR 5: SEP 1, 1995 - AUG 31, 1996	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
GENERAL												
Agreements with senior personnel secured	XXX											
Project evaluation of activities	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Partnership program implementation	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Advisory/oversight committee meetings	XXX						XXX					
Establish technology needs	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Secure commitments from legislature/business	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Meetings of governing body	XXX					XXX						
MULTIDISCIPLINARY SCIENCE CURRIC (MSC)												
4th pilot test of MSC in 15 AEA school districts	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
4th evaluation/revision MSC workshop - 1 week										XXX		
AEA workshop for administrators/teachers - 15						XXX						
Identify new pilot school districts/teachers									XXX			
AEA workshops for new pilot teachers -1 week											XXX	
Adoption of MSC curriculum model												XXX
STAFF DEVELOPMENT												
Staff development & training workshops	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	
Trainer evaluation & revision workshop											XXX	XXX
Dissemination of video production to all districts									XXX	XXX	XXX	
Plan & budget for continuation of staff dev workshops					XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
IOWA SCHOOL STANDARDS												
MSC Iowa standards committee meeting	XXX				XXX							
Develop plan to work with change adopters		XXX	XXX	XXX								
Implement plan					XXX	XXX	XXX	XXX	XXX			
Changes in effect											XXX	XXX
TEACHER CERTIFICATION REQUIREMENTS												
Teacher certification committee meetings	XXX							XXX				
Teacher certification changes in effect									XXX			
TEACHER PREPARATION												
Pilot testing of teacher preparation model	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Teacher preparation task committee meetings	XXX	XXX										
Develop & implement plan to effect changes	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Evaluation/revisions of pilot tests										XXX		
Changes incorporated into all Iowa tchr prep programs											XXX	XXX
YEAR 5: SEP 1, 1995 - AUG 31, 1996	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG

III. A DESCRIPTION OF THE PARTNERS THAT WILL ENGAGE IN IOWA'S INITIATIVE

Iowa's planning process has been a cooperative effort by many organizations and individuals who will have a responsibility to this systemic initiative, and will be instrumental in mobilizing the disciplinary expertise and human and material resources in the implementation of Iowa's initiative to improve mathematics and science education.

An advisory board was formed by the Governor's Office in response to the National Science Foundation's (NSF) solicitation. The board is made up of leaders from state government, educational associations, business and industry, state math and science organizations, area educational agencies, legislators, regents institutions and independent colleges, national and state organizations, and teachers and administrators (see Appendix G for listing). The objective of the advisory board meetings was to identify and discuss problems in science and mathematics as they relate to state and national needs, and to provide the focus for Iowa's proposal to NSF. Once the focus was identified, subgroups were formed and members added to initiate the development of Iowa's preliminary proposal and set the parameters for the development of the statewide systemic initiative. A "Core Committee" from the Iowa Department of Education was formed to coordinate the development of the statewide systemic initiative. This committee was responsible for identifying the "players" and support needed to fulfill the requirements of the NSF solicitation and provide the coordination, guidance, and direction in developing the statewide initiative. An "Action Committee" was formed to solicit support and input from individuals, groups, organizations, and institutions. A "Grant Writing Committee" consisting of experienced science and math educators in the state, was formed to develop the specific goals and objectives of Iowa's initiative and contribute to the writing of the formal proposal. The writing of the formal proposal was done on PSInet (People Sharing Information), a computer conferencing network for science and math educators supported by NSF. This has provided the opportunity for over 100 science and math educators, 15 area education agencies, 10 colleges and universities, 5 Iowa state agencies, and 60 local schools to have input into this proposal. Iowa is the national center for

PSInet, and PSInet will be used extensively in the implementation of Iowa's statewide systemic initiative to improve math and science education throughout the state and country.

A governing body of science and math educators has been selected to oversee and supervise the activities listed in this initiative. Members of the governing body were selected for their expertise and experience in the various facets of this initiative. These members will meet periodically over the course of this initiative with the project evaluator to discuss the progress, results and outcomes of the various activities and make changes in direction if necessary. The member of the governing body and their areas of supervision are:

Dr. Lynn Glass, Iowa State University, Partnership Programs,
Dr. Roy Unruh, University of Northern Iowa, Curriculum and Staff Development Programs,
Dr. Larry Leutzinger, University of Northern Iowa, Curriculum and Staff Development Programs,
Dr. Robert Yager, University of Iowa, Teacher Certification and Preparation Programs,
Dr. John Penick, University of Iowa, Teacher Certification and Preparation Programs,
Dr. Jack Gerlovich, Drake University, School Standards and PSInet Conferencing, and
Dr. W. Tony Heiting, Iowa Department of Education, Project Director.

A model of Iowa's planning process is given in Appendix H.

A SHARED RESPONSIBILITY:
IOWA'S PARTNERSHIP PLAN
FOR IMPROVING SCHOOL SCIENCE AND MATHEMATICS

Transforming school programs is a shared responsibility. The goals for the Iowa systemic initiative focus on increasing the numbers of students in Iowa who choose science, engineering, science/math education as careers. This initiative is concerned with making science and mathematics meaningful for all students. Communities and businesses/industries must support these transformations in Iowa's schools if they are to be lasting. In order for the goals of this project to be realized, this systemic initiative must help students realize how science and mathematics are connected to the real world.

The leadership in Iowa has recognized the need to stimulate collaborative efforts to support and improve school science and mathematics. Four years ago, the Governor of the State of Iowa created the Iowa Alliance for Science and Mathematics. The major purpose of the Alliance is to promote business-school partnerships which can enhance school science, mathematics and technology programs. The charge was conceived to develop local school-business-industry-community alliances to support science, mathematics and technology programs in the schools. An 18 member Governor's Advisory Committee consisting of respected leaders from government, business and industry, and education sponsor a variety of activities, including the Annual Governor's Conference in February. The purpose of these activities is to stimulate interest and awarenesses, recognize successful partnerships, and disseminate resources to schools and communities.

Support for the Governor's Alliance has developed in over 90 local communities. The Iowa Utility Association (IUA), sponsors of the Iowa Chautauqua Program, and the Iowa Chamber of Commerce have been active supporters of the Governor's Alliance. Improving and enhancing science and mathematic/technology education is the major goal of all these groups. Knowing that the most successful collaborative efforts are predicated on cooperation and successes, it seems appropriate at this time to build from the practices and policies that are working effectively to promote more partnerships and unite them even more closely in the goals of this statewide systemic effort.

Educational partnerships are being viewed as positive and necessary to support reform in Iowa schools. This component of the Iowa systemic initiative proposes to use the Governor's

Alliance for Science and Mathematics as the umbrella for improving communication, coordination, and leadership, and for stimulating new initiatives and projects.

The Iowa Partnership Plan for systemic change will focus on:

- stimulating public interest in and support for K-12 science and mathematics education;
- addressing issues of public policy that effect science and mathematics education;
- improving community support systems for science and mathematics teachers;
- increasing the accessibility of available learning resources (both human and material) and
- encouraging their use by teachers in developing interdisciplinary experiences for students.

Under the leadership of the Governor's Iowa Alliance for Science and Mathematics and the Regents Advisory Committee, composed of representatives from the three state universities, an Iowa Partnership Advisory Committee will be formed. Individuals from the following cooperating organizations will be included on this committee: Iowa private colleges; State Department of Education; Iowa Science and Mathematics Teachers Association; Iowa community colleges; Iowa Chamber of Commerce Executives; Iowa Association of School Boards; Iowa PTAs; School Administrators of Iowa; Iowa Association of Business and Industry; Iowa Utility Association; Iowa Chautauqua Program; and Science Center of Iowa. This Advisory Board will be focused on accomplishing the following specific objectives related to building stronger science and mathematics programs:

1. communicate with agencies and organizations interested in science and mathematics education reform;
2. stimulate more school-business-industry partnerships for supporting school science and mathematics programs;
3. involve students and schools in community betterment projects related to science and mathematics;
4. develop a leadership training program in conjunction with the IUA Chautauqua for persons from education and business;
5. produce and distribute a statewide Partnership Newsletter;

6. assist schools in the preparation of proposals for use of Phase III and Eisenhower funds that would stimulate partnerships.

A coordinating institution will be selected and a full time Iowa Partnership Coordinator hired to implement the objectives stated above.

IV. A DESCRIPTION OF THE MEANS BY WHICH PROJECT ACTIVITIES WILL BE EVALUATED AND DOCUMENTED

It is the intention of this project to facilitate systemic change that will result in the development and improvement of science and mathematics instruction in Iowa schools. To this end, it is anticipated that more students will choose science and science related careers, that their general scientific literacy will improve, that student understanding of science will increase, and that students will retain enthusiasm and interest in science. Change of this nature will require that the evaluation component of this project utilize a wide range of information, including documentation of project activities and assessment of various specified project outcomes.

A four level evaluation structure will be implemented. These levels can be defined as follows:

Level 1: Institutional Commitment. All levels of institutional efforts related to the project will be examined, including state, AEAs, and local school districts. Project committee records will be examined in terms of their charge with regard to the goals of the project to modify state certification requirements, to improve teacher preparation course work (especially in terms of appropriate science and math course work and methods), to commit resources to developing and implementing of modified science and math curriculum efforts. Included in this evaluation will also be documents to show that existing policy and changes have occurred.

Level 2: Structural Context. Here changes in formal documents (curriculum guides), arrangements for implementation and physical conditions are considered. Included in this aspect of evaluation will be an examination of the curriculum models, the supportive materials, training workshops, interviews with participating teachers, and development of AEA and local school district committees to further promote the sweeping changes proposed in this project. It is anticipated that these committees will have direct involvement in various aspects of the evaluation process, especially in the review of collected data and identification of formative changes as well as constructing appropriate hands-on achievement exams.

Level 3: Role Performance. The degree of actual implementation is examined and assessed in this aspect of the evaluation. Supportive behavior of the administration, the classroom (and workshop) behaviors of teachers will be observed and examined in terms of the change expected in order to satisfactorily carry out the modifications outlined in this proposal, especially the multidisciplinary science curriculum. It is anticipated that administrators will exhibit greater support and involvement in the modified science programs while teachers will exhibit increased cooperative planning and greater use of hands-on type instruction.

Level 4: Learning Activities. The intention of this project is to facilitate change in terms of science literacy and attitude of students in classrooms. In this aspect of the evaluation, sample documents will be collected, including lesson plans, student projects, video tapes of classroom activities, and student scores on project designed achievement tests as partial evidence that the systemic changes have in fact resulted in change in the classroom and the teaching of science. It is anticipated that teachers will assist in the collecting this data as well as in the construction of the assessment instruments. In addition to standardized tests now available, appropriate hands-on achievement tests will be constructed and administered. These tests are considered to be congruent with the future of the curriculum models proposed in this initiative.

The methodology of this evaluation will combine quasi-experimental designs with ethnographic methods. These approaches will enable maximum use of data in a meaningful form for use by participants and future project reviewers. As documents and assessments are collected, brief summary reports will be made available to those interested, including participants, as a means to help guide and support their efforts in a positive manner. A half-time Project Evaluator has been identified to implement the four level evaluation structure as discussed above.

Throughout the entire length of the project, formative evaluation will occur, assessing in an ongoing manner the progress of the project and identifying any changes needed in the project plan. This evaluation component will provide for input from all participants in the project, from teacher educators to pilot site teachers and administrators. Constant attention will be given to how the project should articulate with education at the high school level.

V. A PLAN FOR DISSEMINATION OF INFORMATION

Iowa is the national host for the CSSS PSInet system, linking all 50 states into an interactive telecommunications network. This initiative will be shared with all states via PSInet. State science and mathematics supervisors will be encouraged to react to the initiative as it unfolds. Educators at all levels within other states will also be asked for opinions of the initiative as it develops and matures. PSInet servers, other than mathematics and science, will also be encouraged to react to the plan. The National Education Association (NEA), for instance, has a PSInet server also, which can be shadowed into the CSSS PSInet server. PSInet is a National Science Foundation project which has proven to be a VERY effective communications network. It saves significant amounts of time and funds for busy professional educators at all levels.

The Iowa Intrastate PSInet system (IADSM) is a maturing telecommunications system, currently linking 200 Iowa science and mathematics educators. This NSF proposal was developed, and refined, in large measure, using this network. The proposed initiative will be implemented and evaluated using the network as necessary. A conference will be dedicated to informing Iowa educators of this precedent setting initiative.

Traditional communications formats, such as newsletters, inservice programs, educational television, presentations at state, regional and national conferences and private business communications will also be incorporated to apprise educators and the public of the project's progress. On-going input will be solicited, and refinements incorporated based upon such dialogue.

BUDGET

AND

BUDGET NARRATIVE

First Year 1991-1992

(SEE INSTRUCTIONS ON REVERSE BEFORE COMPLETING)

SUMMARY PROPOSAL BUDGET

ORGANIZATION Iowa Department of Education	FOR NSF USE ONLY PROPOSAL NO. DURATION (MONTHS): Proposed / Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Dr. W. Anthony Heiting	AWARD NO.

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.6. show number in brackets)	NSF FUNDED PERSON-MOS. CAL.	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
1. W. Tony Heiting, Iowa Department of Education	6			$ 27,000	$
2. Roy Unruh, University of Northern Iowa	3			12,000	
3. Larry Leutzinger, University of Northern Iowa	3			9,000	
4. Lynn Glass, Iowa State University	2			14,000	
5. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
6. (4) TOTAL SENIOR PERSONNEL (1-5)				62,000	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. (6) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				234,000	
3. (6) GRADUATE STUDENTS				30,000	
4. ( ) UNDERGRADUATE STUDENTS					
5. (4) SECRETARIAL-CLERICAL				50,000	
6. (15) OTHER Area Education Agency (AEA) Science/Math Supervisors				360,000	
TOTAL SALARIES AND WAGES (A+B)				736,000	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) 27% less graduate students				190,620	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				926,620	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000.) PSInet Computers - $3,000 each x 60 teachers = $180,000 for lead teachers					
TOTAL PERMANENT EQUIPMENT				180,000	
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				25,720	
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 75,600 2. TRAVEL 14,600 3. SUBSISTENCE 56,190 4. OTHER 3,000 Books					
TOTAL PARTICIPANT COSTS				149,390	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				50,000	
2. PUBLICATION COSTS/PAGE CHARGES				20,000	
3. CONSULTANT SERVICES				50,000	
4. COMPUTER (ADPE) SERVICES				1,000	
5. SUBCONTRACTS					
6. OTHER				5,000	
TOTAL OTHER DIRECT COSTS				126,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				1,407,730	
I. INDIRECT COSTS (SPECIFY) 10.3%					
TOTAL INDIRECT COSTS				129,609	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				1,537,339	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 1,537,339	$

PI/PD TYPED NAME & SIGNATURE* William L. Lepley, Director William L Lepley	DATE 10/12/90	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION
INST. REP. TYPED NAME & SIGNATURE* W. Tony Heiting, Consultant W Tony Heiting	DATE 10/12/90	Date Checked / Date of Rate Sheet / Initials - DGC / Program

NSF Form 1030 (1-87) Supersedes All Previous Editions

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

First year 1991-1992

(SEE INSTRUCTIONS ON REVERSE BEFORE COMPLETING)

SUMMARY PROPOSAL BUDGET

Second year 1992-1993

ORGANIZATION Iowa Department of Education	FOR NSF USE ONLY				
	PROPOSAL NO.		DURATION (MONTHS)		
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Dr. W. Anthony Heiting	AWARD NO.		Proposed	Granted	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.6. show number in brackets)	NSF FUNDED PERSON-MOS. CAL.	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
1. W. Tony Heiting, Iowa Department of Education	6			$ 29,700	$
2. Roy Unruh, University of Northern Iowa	3.5			17,600	
3. Larry Leutzinger, University of Northern Iowa	3.5			13,200	
4. Lynn Glass, Iowa State University	2.0			15,400	
5. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)				See attached	Page
6. (7) TOTAL SENIOR PERSONNEL (1-5)				102,984	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. (7) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				302,400	
3. (7) GRADUATE STUDENTS				38,500	
4. ( ) UNDERGRADUATE STUDENTS					
5. (5) SECRETARIAL CLERICAL				65,000	
6. (15) OTHER Area Education Agency (AEA) Math/Science Supervisors				396,000	
TOTAL SALARIES AND WAGES (A+B)				904,884	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) 27% less graduate student costs				226,611	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				1,131,495	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				31,292	
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 134,400					
2. TRAVEL 29,280					
3. SUBSISTENCE 97,880					
4. OTHER 12,000					
TOTAL PARTICIPANT COSTS				273,560	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				100,000	
2. PUBLICATION COSTS/PAGE CHARGES				40,000	
3. CONSULTANT SERVICES				50,000	
4. COMPUTER (ADPE) SERVICES				2,000	
5. SUBCONTRACTS					
6. OTHER				5,000	
TOTAL OTHER DIRECT COSTS				197,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				1,633,347	
I. INDIRECT COSTS (SPECIFY)					
TOTAL INDIRECT COSTS 10.3%				140,058	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				1,773,405	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$1,773,405	$

PI/PD TYPED NAME & SIGNATURE* William L. Lepley, Dir. William Lepley	DATE 10/12/90	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION
INST. REP. TYPED NAME & SIGNATURE* W. Tony Heiting, Consultant W. Tony Heiting	DATE 10/12/90	Date Checked / Date of Rate Sheet / Initials - DGC / Program

NSF Form 1030 (1-87) Supersedes All Previous Editions

* *SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

Second Year 1992-1993

(SEE INSTRUCTIONS ON REVERSE BEFORE COMPLETING)

SUMMARY Page 2, Second Year 1992-1998
PROPOSAL BUDGET

ORGANIZATION Iowa Department of Education	FOR NSF USE ONLY PROPOSAL NO.	DURATION (MONTHS) Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Dr. W. Anthony Heiting	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	NSF FUNDED PERSON-MOS. CAL.	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
1. John Penick, University of Iowa	2.0			$ 15,400	$
2. Jack Gerlovich, Drake University	1.0			3,300	
3. Robert Yager, University of Iowa	1.0			8,384	
4.					
5. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)				-	
6. ( ) TOTAL SENIOR PERSONNEL (1-5)					
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. ( ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)					
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL-CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)					
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)					
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)					
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000:)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ ______ 2. TRAVEL ______ 3. SUBSISTENCE ______ 4. OTHER ______					
TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES					
2. PUBLICATION COSTS/PAGE CHARGES					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER					
TOTAL OTHER DIRECT COSTS					
H. TOTAL DIRECT COSTS (A THROUGH G)					
I. INDIRECT COSTS (SPECIFY)					
TOTAL INDIRECT COSTS					
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)					
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$	$

PI/PD TYPED NAME & SIGNATURE* William L. Lepley, Director William L Lepley	DATE 10/12/90	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
INST. REP. TYPED NAME & SIGNATURE* W. Tony Heiting, Cons. W. Tony Heiting	DATE 10/12/90	Date Checked	Date of Rate Sheet	Initials - DGC Program

NSF Form 1030 (1-87) Supersedes All Previous Editions

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

(SEE INSTRUCTIONS ON REVERSE BEFORE COMPLETING)

SUMMARY PROPOSAL BUDGET

Third year, 1993-1994

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (MONTHS)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION: Iowa Department of Education

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR: Dr.W. Anthony Heiting

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	NSF FUNDED PERSON-MOS. CAL.	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
1. W. Tony Heiting, Iowa Department of Education	6.0			$ 32,670	$
2. Roy Unruh, University of Northern Iowa	3.5			19,360	
3. Larry Leutzinger, University of Northern Iowa	3.5			14,520	
4. Lynn Glass, Iowa State University	2.0			16,940	
5. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)				See Attached	Page
6. (7) TOTAL SENIOR PERSONNEL (1-5)				120,542	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. (37) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				467,590	
3. (7) GRADUATE STUDENTS				42,350	
4. ( ) UNDERGRADUATE STUDENTS					
5. (5) SECRETARIAL CLERICAL				71,500	
6. (15) OTHER Area Education Agency (AEA) Math/Science Supervisors				435,600	
TOTAL SALARIES AND WAGES (A+B)				1,137,582	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) 27% less graduate student cost				295,713	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				1,433,295	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				34,421	
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 1,115,800					
2. TRAVEL 25,620					
3. SUBSISTENCE 86,320					
4. OTHER 12,000					
TOTAL PARTICIPANT COSTS				1,239,740	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				110,000	
2. PUBLICATION COSTS/PAGE CHARGES				80,000	
3. CONSULTANT SERVICES				50,000	
4. COMPUTER (ADPE) SERVICES				3,000	
5. SUBCONTRACTS					
6. OTHER Community Colleges, Telecommunications Costs				204,000	
TOTAL OTHER DIRECT COSTS				447,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				3,154,456	
I. INDIRECT COSTS (SPECIFY)					
TOTAL INDIRECT COSTS 10.3%				197,216	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				3,351,672	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$3,351,672	$

PI/PD TYPED NAME & SIGNATURE* William L. Lepley, Director	DATE 10/12/90
INST. REP. TYPED NAME & SIGNATURE* W. Tony Heiting W. Tony Heiting	DATE 10/12/90

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date of Rate Sheet	Initials - DGC
		Program

NSF Form 1030 (1-87) Supersedes All Previous Editions

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

Third Year 1993-1994

REVERSE BEFORE COMPLETING)

SUMMARY PROPOSAL BUDGET

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (MONTHS)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
Iowa Department of Education

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR
Dr. W. Tony Heiting

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	NSF FUNDED PERSON-MOS. CAL.	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
1. John Penick, University of Iowa	2.0			$ 16,940	$
2. Jack Gerlovich, Drake University	3.0			10,890	
3. Robert Yager, University of Iowa	1.0			9,222	
4.					
5. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
6. ( ) TOTAL SENIOR PERSONNEL (1-5)					
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. ( ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)					
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL-CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)					
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)					
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)					
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $					
2. TRAVEL					
3. SUBSISTENCE					
4. OTHER					
TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES					
2. PUBLICATION COSTS/PAGE CHARGES					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER					
TOTAL OTHER DIRECT COSTS					
H. TOTAL DIRECT COSTS (A THROUGH G)					
I. INDIRECT COSTS (SPECIFY)					
TOTAL INDIRECT COSTS					
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)					
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$	$

PI/PD TYPED NAME & SIGNATURE* William L. Lepley, Director	DATE 10/12/90	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION
INST. REP. TYPED NAME & SIGNATURE* W. Tony Heiting, Cons. W. Tony Heiting	DATE 10/12/90	Date Checked / Date of Rate Sheet / Initials - OGC / Program

NSF Form 1030 (1-87) Supersedes All Previous Editions

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

(SEE INSTRUCTIONS ON
REVERSE BEFORE
COMPLETING)

SUMMARY PROPOSAL BUDGET

Fourth Year 1994-1995

FOR NSF USE ONLY			
PROPOSAL NO.	DURATION (MONTHS)		
	Proposed	Granted	
AWARD NO.			

ORGANIZATION
Iowa Department of Education

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR
Dr. W. Anthony Heiting

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	NSF FUNDED PERSON MOS. CAL.	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
1. W. Tony Heiting, Iowa Department of Education	6.0			$ 35,937	$
2. Roy Unruh, University of Northern Iowa	3.5			21,296	
3. Larry Leutzinger, University of Northern Iowa	3.5			15,972	
4. Lynn Glass, Iowa State University	2.0			18,634	
5. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)				See Attached Page	
6. (7) TOTAL SENIOR PERSONNEL (1-5)				141,086	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. (37) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				500,849	
3. (7) GRADUATE STUDENTS				46,585	
4. ( ) UNDERGRADUATE STUDENTS					
5. (5) SECRETARIAL-CLERICAL				78,650	
6. (15) OTHER Area Education Agency (AEA) Math/Science Supervisors				479,160	
TOTAL SALARIES AND WAGES (A+B)				1,246,330	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) 27% less graduate student costs				323,931	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				1,570,261	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				37,863	
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 1,103,200					
2. TRAVEL 21,840					
3. SUBSISTENCE 71,560					
4. OTHER 13,200					
TOTAL PARTICIPANT COSTS				1,209,800	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				163,600	
2. PUBLICATION COSTS/PAGE CHARGES				100,000	
3. CONSULTANT SERVICES				50,000	
4. COMPUTER (ADPE) SERVICES				5,000	
5. SUBCONTRACTS					
6. OTHER Community Colleges, Telecommunications/video costs				234,400	
TOTAL OTHER DIRECT COSTS				553,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				3,370,924	
I. INDIRECT COSTS (SPECIFY)					
TOTAL INDIRECT COSTS 10.3%				222,596	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				3,593,520	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$3,593,520	$

PI/PD TYPED NAME & SIGNATURE* William L. Lepley, Director	DATE 10/12/90	FOR NSF USE ONLY		
		INDIRECT COST RATE VERIFICATION		
INST. REP. TYPED NAME & SIGNATURE* W. Tony Heiting, Cons. W. Tony Heiting	DATE 10/12/90	Date Checked	Date of Rate Sheet	Initials - DGC Program

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*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

Fourth Year 1994-1995

(SEE INSTRUCTIONS ON
REVERSE BEFORE
COMPLETING)

SUMMARY Fourth Year (con't.)
PROPOSAL BUDGET

ORGANIZATION Iowa Department of Education	FOR NSF USE ONLY		
	PROPOSAL NO.	DURATION (MONTHS)	
		Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR W. Anthony Heiting	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	NSF FUNDED PERSON-MOS.			FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
	CAL.	ACAD	SUMR		
1. John Penick, University of Iowa	2.0			$ 18,634	$
2. Jack Gerlovich, Drake University	3.0			11,979	
3. Robert Yager, University of Iowa	2.0			18,634	
4.					
5. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
6. ( ) TOTAL SENIOR PERSONNEL (1-5)					
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. ( ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)					
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL-CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)					
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)					
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)					
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $					
2. TRAVEL					
3. SUBSISTENCE					
4. OTHER					
TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES					
2. PUBLICATION COSTS/PAGE CHARGES					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER					
TOTAL OTHER DIRECT COSTS					
H. TOTAL DIRECT COSTS (A THROUGH G)					
I. INDIRECT COSTS (SPECIFY)					
TOTAL INDIRECT COSTS					
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)					
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$	$

PI/PD TYPED NAME & SIGNATURE* William L. Lepley, Director	DATE 10/12/90	FOR NSF USE ONLY		
		INDIRECT COST RATE VERIFICATION		
INST. REP. TYPED NAME & SIGNATURE* W. Tony Heiting, Cons. W. Tony Heiting	DATE 10/12/90	Date Checked	Date of Rate Sheet	Initials - DGC Program

NSF Form 1030 (1-87) Supersedes All Previous Editions

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

(SEE INSTRUCTIONS ON REVERSE BEFORE COMPLETING)

SUMMARY PROPOSAL BUDGET

Fifth Year 1995-1996

ORGANIZATION Iowa Department of Education	FOR NSF USE ONLY
	PROPOSAL NO.
	DURATION (MONTHS): Proposed / Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Dr. W. Anthony Heiting	AWARD NO.

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	NSF FUNDED PERSON-MOS. CAL.	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
1. W. Tony Heiting, Iowa Department of Education	6.0			$ 39,530	$
2. Roy Unruh, University of Northern Iowa	3.5			23,425	
3. Larry Leutzinger, University of Northern Iowa	3.5			17,569	
4. Lynn Glass, Iowa State University	2.0			20,497	
5. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)				See Attached Page	
6. (7) TOTAL SENIOR PERSONNEL (1-5)				155,191	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. (37) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				537,430	
3. (7) GRADUATE STUDENTS				51,243	
4. ( ) UNDERGRADUATE STUDENTS					
5. (5) SECRETARIAL-CLERICAL				86,515	
6. (15) OTHER Area Education Agency (AEA) Math/Science Supervisors				545,076	
TOTAL SALARIES AND WAGES (A+B)				1,375,455	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) 27% less graduate student costs				357,537	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				1,732,992	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				41,649	
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 1,100,200					
2. TRAVEL 19,740					
3. SUBSISTENCE 70,920					
4. OTHER 14,520					
TOTAL PARTICIPANT COSTS				1,205,380	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				179,960	
2. PUBLICATION COSTS/PAGE CHARGES				110,100	
3. CONSULTANT SERVICES				50,000	
4. COMPUTER (ADPE) SERVICES				3,000	
5. SUBCONTRACTS					
6. OTHER Community Colleges, Telecommunications, video costs				330,500	
TOTAL OTHER DIRECT COSTS				673,560	
H. TOTAL DIRECT COSTS (A THROUGH G)				3,653,581	
I. INDIRECT COSTS (SPECIFY)					
TOTAL INDIRECT COSTS 10.3%				252,165	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				3,905,746	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$3,905,746	$

PI/PD TYPED NAME & SIGNATURE* William L. Lepley, Director William Lepley	DATE 10/12/90	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION
INST. REP. TYPED NAME & SIGNATURE* W. Tony Heiting, Cons. W. Tony Heiting	DATE 10/12/90	Date Checked / Date of Rate Sheet / Initials - DGC / Program

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Fifth Year 1995-1996

(SEE INSTRUCTIONS ON REVERSE BEFORE COMPLETING)

SUMMARY Fifth Year (con't.)
PROPOSAL BUDGET

FOR NSF USE ONLY			
PROPOSAL NO.		DURATION (MONTHS)	
		Proposed	Granted
AWARD NO.			

ORGANIZATION
Iowa Department of Education

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR
Dr. W. Anthony Heiting

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	NSF FUNDED PERSON-MOS. CAL.	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
1. John Penick, University of Iowa	2.0			$ 20,497	$
2. Jack Gerlovich, Drake University	3.0			13,176	
3. Robert Yager, University of Iowa	2.0			20,497	
4.					
5. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
6. ( ) TOTAL SENIOR PERSONNEL (1-5)					
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. ( ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)					
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)					
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)					
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)					
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 2. TRAVEL 3. SUBSISTENCE 4. OTHER					
TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES					
2. PUBLICATION COSTS/PAGE CHARGES					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER					
TOTAL OTHER DIRECT COSTS					
H. TOTAL DIRECT COSTS (A THROUGH G)					
I. INDIRECT COSTS (SPECIFY)					
TOTAL INDIRECT COSTS					
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)					
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$	$

PI/PD TYPED NAME & SIGNATURE* William L. Lepley, Director	DATE 10/12/90	FOR NSF USE ONLY		
		INDIRECT COST RATE VERIFICATION		
INST. REP. TYPED NAME & SIGNATURE* W. Tony Heiting, Cons. W. Tony Heiting	DATE 10/12/90	Date Checked	Date of Rate Sheet	Initials - DGC Program

NSF Form 1030 (1-87) Supersedes All Previous Editions

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

Page 2 Fifth Year 1995-1996

REVERSE BEFORE COMPLETING)

PROPOSAL BUDGET

ORGANIZATION Iowa Department of Education	FOR NSF USE ONLY PROPOSAL NO.
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Dr. W. Anthony Heiting	AWARD NO.

	DURATION (MONTHS)
Proposed	Granted

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	NSF FUNDED PERSON-MOS. CAL.	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
1. W. Tony Heiting, Iowa Department of Education				$ 164,837	$
2. Roy Unruh, University of Northern Iowa				93,681	
3. Larry Leutzinger, University of Northern Iowa				70,261	
4. Lynn Glass, Iowa State University				85,471	
5. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)				See Attached Page	
6. (7) TOTAL SENIOR PERSONNEL (1-5)				581,803	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. (37) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				2,042,269	
3. (*7) GRADUATE STUDENTS				208,678	
4. ( ) UNDERGRADUATE STUDENTS					
5. (5) SECRETARIAL CLERICAL				351,665	
6. (15) OTHER Area Education Agency (AEA) Math/Science Supervisors				2,215,836	
TOTAL SALARIES AND WAGES (A+B)				5,400,251	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) 27% less graduate student costs				1,394,412	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				6,794,663	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000.) Computers for lead teachers to join PSInet communications network. (60 teachers x 3,000 computers)					
TOTAL PERMANENT EQUIPMENT				180,000	
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				170,945	
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 3,529,200 2. TRAVEL 111,080 3. SUBSISTENCE 382,870 4. OTHER 54,720					
TOTAL PARTICIPANT COSTS				4,077,870	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				603,560	
2. PUBLICATION COSTS/PAGE CHARGES				350,100	
3. CONSULTANT SERVICES				250,000	
4. COMPUTER (ADPE) SERVICES				14,000	
5. SUBCONTRACTS					
6. OTHER				778,900	
TOTAL OTHER DIRECT COSTS				1,996,560	
H. TOTAL DIRECT COSTS (A THROUGH G)				13,220,038	
I. INDIRECT COSTS (SPECIFY) 10.3%					
TOTAL INDIRECT COSTS				941,644	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				14,161,682	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$14,161,682	$

PI/PD TYPED NAME & SIGNATURE* William L. Lepley, Director	DATE 10/12/90	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION
INST. REP. TYPED NAME & SIGNATURE* W. Tony Heiting, Cons. W. Tony Heiting	DATE 10/12/90	Date Checked / Date of Rate Sheet / Initials - DGC / Program

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CUMULATIVE 1991-1996

REVERSE BEFORE
COMPLETING)

SUMMARY
PROPOSAL BUDGET

CUMULATIVE (CON. ..) 1991-1996

ORGANIZATION Iowa Department of Education				FOR NSF USE ONLY PROPOSAL NO.	DURATION (MONTHS)
					Proposed | Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Dr. W. Anthony Heiting				AWARD NO.	
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title; A.6. show number in brackets)	NSF FUNDED PERSON-MOS. CAL.	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
1. John Penick, University of Iowa					
2. Jack Gerlovich, Drake University				$ 71,471	$
3. Robert Yager, University of Iowa				39,345	
4.				56,737	
5. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
6. ( ) TOTAL SENIOR PERSONNEL (1-5)					
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES	▨	▨	▨	▨	▨
2. ( ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)					
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL-CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)					
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)					
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)					
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000:)				▨	▨
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)					
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS				▨	▨
1. STIPENDS $ ______					
2. TRAVEL ______					
3. SUBSISTENCE ______					
4. OTHER ______					
TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				▨	▨
2. PUBLICATION COSTS/PAGE CHARGES					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER					
TOTAL OTHER DIRECT COSTS					
H. TOTAL DIRECT COSTS (A THROUGH G)					
I. INDIRECT COSTS (SPECIFY)					
TOTAL INDIRECT COSTS					
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)					
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$	$

PI/PD TYPED NAME & SIGNATURE* William L. Lepley, Director William L. Lepley	DATE 10/12/90	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION
INST. REP. TYPED NAME & SIGNATURE* W. Tony Heiting, Cons. W. Tony Heiting	DATE 10/12/90	Date Checked | Date of Rate Sheet | Initials - OGC | Program

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*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

,9

CUMULATIVE 1991-1996

BUDGET EXPLANATION PAGE
YEAR ONE
1991-1992

A.	Senior Personnel		
	1. W. Tony Heiting, 6 months	27,000	
	2. Roy Unruh, 3 months,	12,000	
	3. Larry Leutzinger, 3 months	9,000	
	4. Lynn Glass, 2 months	14,000	
TOTAL SENIOR PERSONNEL		62,000	
B.	Other Personnel		
	1. DE Project Coordinator, 12 months	55,000	
	2. Technology Consultant, 6 months	20,000	
	3. Partnership Project Coordinator, 12 months	45,000	
	4. John Wilson, Evaluator, 6 months	24,000	
	5. Curriculum Activity Coordinator	45,000	
	6. Staff Development Activity Coordinator	45,000	
	7. 6 Graduate Students, 1/2 time	30,000	
	8. 4 Secretarial (1 full time, others part-time)	50,000	
	9. 15 AEA Science/Math Supervisors (half time) ($4000 a month x 16 x 6 months)	360,000	
TOTAL OTHER PERSONNEL		674,000	
TOTAL SALARIES			736,000
C.	Fringe Benefits (27% of salaries minus graduate students)		190,620
D.	Permanent Equipment PSInet Computers for 60 Lead Teachers $3,000 x 60		180,000
E.	Travel Senior Personnel, Activity Coordinators, Project Evaluator, DE Coordinator, (state rate of $.21 per mile)		25,720
F.	Participant Support Cost		
	1. Stipends (Lead Teachers for 21 days at $60.00 per day) 60 x $60 x 21 days	75,600	
	2. Travel ($.21 a mile)	14,600	
	3. Food-$16 a day; lodging-$30 a day; state rate	56,190	
	4. Other - Publications for Lead Teachers	3,000	
TOTAL SUPPORT COSTS			149,390
G.	Other Direct Costs		
	1. Materials & supplies for 5 major activities a. Instructional materials b. Start up supplies	50,000	
	2. Publication costs (five activities)	20,000	

3.	Consultant Services, to draw from Science/Math educator pool for consultation	50,000	
4.	Computer services	1,000	
5.	Sub contract	0	
6.	Other office communications	5,000	
TOTAL OTHER DIRECT COSTS			126,000
H.	Total Direct Costs		1,407,730
I.	Indirect Costs (10.3% of total Direct Costs less Participant Cost)		129,609
J.	Total Direct and Indirect		1,537,339
K.	Residual Funds		0
L.	Amount of This Request		1,537,339

BUDGET EXPLANATION PAGE
YEAR TWO
1992-1993

A.		Senior Personnel		
	1.	W. Tony Heiting, 6 months	29,700	
	2.	Roy Unruh, 3.5 months,	17,600	
	3.	Larry Leutzinger, 3.5 months	13,200	
	4.	Lynn Glass, 1 months	15,400	
	5.	John Penick, 2 months	15,400	
	6.	Jack Gerlovich, 1 month	3,300	
	7.	Robert Yager, 1 month	8,384	
TOTAL SENIOR PERSONNEL			102,984	
B.		Other Personnel		
	1.	DE Project Coordinator, 12 months	60,500	
	2.	Technology Consultant, 6 months	22,000	
	3.	Partnership Project Coordinator, 12 months	49,500	
	4.	John Wilson, Evaluator, 6 months	26,400	
	5.	Curriculum Activity Coordinator	49,500	
	6.	Staff Development Activity Coordinator	49,500	
	7.	7 Graduate Students, 1/2 time	38,500	
	8.	5 Secretarial (1 full time, others part-time)	65,000	
	9.	15 AEA Science/Math Supervisors (half time) ($4000 a month x 16 x 6 months)	396,000	
	10.	Teacher Preparation Activity Coordinator	45,000	
TOTAL OTHER PERSONNEL			801,900	
TOTAL SALARIES				904,884
C.		Fringe Benefits (27% of salaries minus graduate students)		226,611
D.		Permanent Equipment		0
E.		Travel Senior Personnel, Activity Coordinators, Project Evaluator, and Technology Consultant		31,292
F.		Participant Support Cost		
	1.	Stipends		
		a. Lead Teachers (60 x $60 x 10 days)	36,000	
		b. 240 Pilot Trainees(240 x $60 x 5 days)	72,000	
		c. Trainers-staff develop. (30 x $60 x 10 days)	18,000	
		d. Standards Committee (20 x $60 x 2 days)	2,400	
		e. Teacher Preparation Task Force (30 x $60 x 2 days)	3,600	
		f. Teacher Certification Committee (20 x $60 x 2 days)	2,400	
	2.	Travel (participants a through f above-$.21 a mile)	29,280	
	3.	Subsistence, food-$16 a day; lodging-$30 a day	97,880	
	4.	Other - manuals, books	12,000	
TOTAL PARTICIPANT SUPPORT COSTS				273,560

G.	Other Direct Costs		
	1. Materials & supplies for 5 major activities		
	a. Instructional materials	100,000	
	2. Publication costs (five activities)	40,000	
	3. Consultant Services, (to draw from Science/Math educator pool for consultation)	50,000	
	4. Computer services	2,000	
	5. Sub contract	0	
	6. Other office communications	5,000	
TOTAL OTHER DIRECT COSTS			197,000
H.	Total Direct Costs		1,633,347
I.	Indirect Costs (10.3% of total Direct Costs less Participant Cost)		140,058
J.	Total Direct and Indirect		1,773,405
K.	Residual Funds		0
L.	Amount of This Request		1,773,405

BUDGET EXPLANATION PAGE
YEAR THREE
1993-1994

A.	Senior Personnel		
	1. W. Tony Heiting, 6 months	32,670	
	2. Roy Unruh, 3.5 months,	19,360	
	3. Larry Leutzinger, 3.5 months	14,520	
	4. Lynn Glass, 1 months	16,940	
	5. John Penick, 2 months	16,940	
	6. Jack Gerlovich, 3 months	10,890	
	7. Robert Yager, 1 month	9,222	
TOTAL SENIOR PERSONNEL		120,542	
B.	Other Personnel		
	1. DE Project Coordinator, 12 months	66,500	
	2. Technology Consultant, 6 months	24,200	
	3. Partnership Project Coordinator, 12 months	54,450	
	4. John Wilson, Evaluator, 6 months	29,040	
	5. Curriculum Activity Coordinator	54,450	
	6. Staff Development Activity Coordinator	54,450	
	7. 7 Graduate Students, 1/2 time	42,350	
	8. 5 Secretarial (1 full time, others part-time)	71,500	
	9. 15 AEA Science/Math Consultants (half time)	435,600	
	10. Teacher Preparation Activity Coordinator	49,500	
	11. 30 Staff Development Instructors (30 x $75 an hour x 30 hours x 2 courses per year). The $75 per hour rate includes preparation time, instructional time, travel and subsistence	135,000	
TOTAL OTHER PERSONNEL		1,017,440	
TOTAL SALARIES			1,137,582
C.	Fringe Benefits (27% of salaries minus graduate students)		295,713
D.	Permanent Equipment		0
E.	Travel Senior Personnel, Activity Coordinators, Project Evaluator, and Technology Consultant		34,421
F.	Participant Support Cost		
	1. Stipends		
	a. Lead Teachers (60 x $60 x 5 days)	18,000	
	b. 240 New Pilot Trainees (240 x $60 x 5 days)	72,000	
	c. Trainers-staff develop. (15 x $60 x 10 days)	9,000	
	d. Standards Committee (20 x $60 x 3 days)	3,600	
	e. Teacher Preparation Task Force (30 x $60 x 4 days)	7,200	
	f. Teacher Certification Committee (20 x $60 x 2 days)	2,400	
	g. Teacher staff develop. (4000 x $250; for 30 hours of instruction)	1,000,000	

	h. Trainer Evaluation Workshops (30 x $60 x 2 days)	3,600	
2.	Travel (participants a through f above-$.21 a mile)	25,620	
3.	Subsistence, food-$16 a day; lodging-$30 a day	86,320	
4.	Other - manuals, books	12,000	
TOTAL PARTICIPANT SUPPORT COSTS			1,239,740
G.	Other Direct Costs		
1.	Materials & supplies for all activities	110,000	
2.	Publication costs (for all activities)	80,000	
3.	Consultant Services, to draw from Science/Math educator pool for consultation	50,000	
4.	Computer services	3,000	
5.	Sub contract	0	
6.	Other		
	a. Community Colleges classroom rental	120,000	
	b. use of telecommunications network (uplinks and downlink sites)	84,000	
TOTAL OTHER DIRECT COSTS			447,000
H.	Total Direct Costs		3,154,456
I.	Indirect Costs (10.3% of total Direct Costs less Participant Cost)		197,216
J.	Total Direct and Indirect		3,351,672
K.	Residual Funds		0
L.	Amount of This Request		3,351,672

BUDGET EXPLANATION PAGE
YEAR FOUR
1994-1995

A.	Senior Personnel		
	1. W. Tony Heiting, 6 months	35,937	
	2. Roy Unruh, 3.5 months,	21,296	
	3. Larry Leutzinger, 3.5 months	15,972	
	4. Lynn Glass, 1 months	18,634	
	5. John Penick, 2 months	18,634	
	6. Jack Gerlovich, 3 months	11,979	
	7. Robert Yager, 1 month	18,634	
TOTAL SENIOR PERSONNEL		141,086	
B.	Other Personnel		
	1. DE Project Coordinator, 12 months	73,150	
	2. Technology Consultant, 6 months	26,620	
	3. Partnership Project Coordinator, 12 months	59,895	
	4. John Wilson, Evaluator, 6 months	31,944	
	5. Curriculum Activity Coordinator	59,895	
	6. Staff Development Activity Coordinator	59,895	
	7. 7 Graduate Students, 1/2 time	46,585	
	8. 5 Secretarial (1 full time, others part-time)	78,650	
	9. 15 AEA Science/Math Consultants (half time)	479,160	
	10. Teacher Preparation Activity Coordinator	54,450	
	11. 30 Staff Development Instructors (30 x $75 an hour x 30 hours x 2 courses per year) The $75 per hour rate includes preparation time, instructional time, travel and subsistence	135,000	
TOTAL OTHER PERSONNEL		1,105,244	
TOTAL SALARIES			1,246,330
C.	Fringe Benefits (27% of salaries minus graduate students)		323,931
D.	Permanent Equipment		0
E.	Travel Senior Personnel, Activity Coordinators, Project Evaluator, and Technology Consultant		37,863
F.	Participant Support Cost		
	1. Stipends		
	a. Lead Teachers (60 x $60 x 5 days)	18,000	
	b. 240 New Pilot Trainees (240 x $60 x 5 days)	72,000	
	c. Standards Committee (20 x $60 x 3 days)	3,600	
	d. Teacher Preparation Task Force (30 x $60 x 2 days)	3,600	
	e. Teacher Certification Committee (20 x $60 x 2 days)	2,400	
	f. Teacher staff develop. (4000 x $250 (or 30 hours of instruction)	1,000,000	

		g. Trainer Evaluation Workshops (30 x $60 x 2 days)	3,600	
	2.	Travel (participants a through g above-$.21 a mile)	21,840	
	3.	Subsistence, food-$16 a day; lodging-$30 a day	71,560	
	4.	Other - manuals, books	13,200	
TOTAL PARTICIPANT SUPPORT COSTS				1,209,800
G.	Other Direct Costs			
	1.	Materials & supplies for all activities	163,600	
	2.	Publication costs (for all activities)	100,000	
	3.	Consultant Services, to draw from Science/Math educator pool for consultation	50,000	
	4.	Computer services	5,000	
	5.	Sub contract	0	
	6.	Other		
		a. Community Colleges classroom rental	132,000	
		b. use of telecommunications network (uplinks and downlink sites)	102,400	
TOTAL OTHER DIRECT COSTS				553,000
H.	Total Direct Costs			3,370,924
I.	Indirect Costs (10.3% of total Direct Costs less Participant Cost)			222,596
J.	Total Direct and Indirect			3,593,520
K.	Residual Funds			0
L.	Amount of This Request			3,593,520

BUDGET EXPLANATION PAGE
YEAR FIVE
1995-1996

A.	Senior Personnel		
	1. W. Tony Heiting, 6 months	39,530	
	2. Roy Unruh, 3.5 months,	23,425	
	3. Larry Leutzinger, 3.5 months	17,569	
	4. Lynn Glass, 1 months	20,497	
	5. John Penick, 2 months	20,497	
	6. Jack Gerlovich, 3 months	13,176	
	7. Robert Yager, 1 month	20,497	
TOTAL SENIOR PERSONNEL		155,191	
B.	Other Personnel		
	1. DE Project Coordinator, 12 months	80,465	
	2. Technology Consultant, 6 months	29,280	
	3. Partnership Project Coordinator, 12 months	65,884	
	4. John Wilson, Evaluator, 6 months	35,138	
	5. Curriculum Activity Coordinator	65,884	
	6. Staff Development Activity Coordinator	65,884	
	7. 7 Graduate Students, 1/2 time	51,243	
	8. 5 Secretarial (1 full time, others part-time)	86,515	
	9. 15 AEA Science/Math Consultants (half time)	545,076	
	10. Teacher Preparation Activity Coordinator	59,895	
	11. 30 Staff Develfopment Instructors (30 x $75 an hour x 30 hours x 2 courses per year) The $75 per hour rate includes preparation time, instructional time, travel and subsistence	135,000	
TOTAL OTHER PERSONNEL		1,220,264	
TOTAL SALARIES			1,375,455
C.	Fringe Benefits (27% of salaries minus graduate students)		357,537
D.	Permanent Equipment		0
E.	Travel Senior Personnel, Activity Coordinators, Project Evaluator, and Technology Consultant		41,649
F.	Participant Support Cost		
	1. Stipends		
	a. Lead Teachers (60 x $60 x 5 days)	18,000	
	b. 240 New Pilot Trainees (240 x $60 x 5 days)	72,000	
	c. Standards Committee (20 x $60 x 2 days)	2,400	
	d. Teacher Preparation Task Force (30 x $60 x 1 days)	1,800	
	e. Teacher Certification Committee (20 x $60 x 2 days)	2,400	
	f. Teacher staff develop. (4000 x $250; for 30 hours of instruction)	1,000,000	
	g. Trainer Evaluation Workshops (30 x $60		

		x 2 days)	3,600	
	2.	Travel (participants a through g above-$.21 a mile)	19,740	
	3.	Subsistence, food-$16 a day; lodging-$30 a day	70,920	
	4.	Other - manuals, books	14,520	
TOTAL PARTICIPANT SUPPORT COSTS				1,205,380
G.	Other Direct Costs			
	1.	Materials & supplies for all activities	179,960	
	2.	Publication costs (for all activities)	110,100	
	3.	Consultant Services, to draw from Science/Math educator pool for consultation	50,000	
	4.	Computer services	3,000	
	5.	Sub contract	0	
	6.	Other		
		a. Community Colleges classroom rental	145,000	
		b. use of telecommunications network (uplinks and downlink sites)	163,000	
		c. Video dissemination costs	22,500	
TOTAL OTHER DIRECT COSTS				673,560
H.	Total Direct Costs			3,653,581
I.	Indirect Costs (10.3% of total Direct Costs less Participant Cost)			252,165
J.	Total Direct and Indirect			3,905,746
K.	Residual Funds			0
L.	Amount of This Request			3,905,746

BUDGET EXPLANATION PAGE
CUMULATIVE

A. **Senior Personnel**
This will buy 97 months of time from the seven senior personnel who are the principle supervisors for all major activities of this initiative.

TOTAL SALARIES 581,803

B. **Other Personnel**
This category includes the Department of Education Project Coordinator, and full time project coordinators for four of the major activities in this initiative: The Partnership Program; Curriculum Development; Staff Development and Teacher Preparation. This category also includes a half-time Technology Consultant and Project Evaluator of all activities. Secretarial and graduate assistant support is covered in this category. Fifteen Area Education Agency math/science supervisors involved in curriculum and staff development activities on a half-time basis are included here along with thirty staff development instructors. A total 64 professionals fall in this category.

TOTAL SALARIES 4,818,448

C. **Fringe Benefits**
The fringe benefit percentage of 27% is the average at the regents institutions. The fringe benefit percentage was applied to the salaries of senior personnel and 57 other personnel for the five year period. Graduate students costs were not part of this calculation.

1,394,412

D. **Permanent Equipment**
60 computers estimated at $3,000 per computer will be bought for the 60 Lead Teachers in the first year to communicate and share their developing curriculum modules via the PSInet communications network. 180,000

E. **Travel**
Includes travel expenses based on state rate of $0.21 per miles (in-state) for DE coordinator, activity coordinators (4), senior personnel (7), technology consultant, and project evaluator. Includes in-state and out-of-state travel. 170,945

F.	**Participant Support Costs** This category includes stipends, travel and subsistence for an estimated 12,825 math and science teachers participating in curriculum development and staff development activities over the five year period. This category also includes costs for 70 other math and science educators participating in other activities and functions of this initiative. The NSF stipend rate of $60.00 per day was applied along with the state rates of $0.21 per mile, up to $16.00/day for food, and $30.00/day for lodging.		4,077,870
G.	**Other Direct Costs**		
	1. Materials and Supplies This includes all materials and supplies for all activities in this initiative.	603,560	
	2. Publications Costs For all activities in this initiative.	350,100	
	3. Consultant Services Consultants in math and science from the various colleges, universities and organizations will be asked to provide consultating services in all of the various activities. This category also includes consultants brought in from outside the state.	250,000	
	4. Computer Services	14,000	
	5. Sub contracts	0	
	6. Other This includes special books, manuals, etc. needed for curriculum and staff development efforts. Included in this category is rental of 20 community college classrooms, the use of the three Iowa telecommunication uplinks and 90 downlink sites, and the production and dissemination of a video for staff development purposes.	778,900	
TOTAL OTHER DIRECT COSTS			1,996,560
H.	**Total Direct Costs**		13,220,038
I.	**Indirect Costs** (10.3% of Total) Direct Costs less Participant Cost		941,644
J.	**Total Direct and Indirect**		14,161,682
K.	**Residual Funds**		0
L.	**Amount of This Project**		14,161,682

COST SHARING STATEMENT

Part 1: Financial Commitment by Partners

Partner	Cash Contributions Annual/Cumulative	In-kind Contributions (Description & Dollar Value)
Iowa Legislature	$1,000,000/5,000,000	
Iowa Dept of Education (Eisenhower Funds)	$47,000/$235,000	
Support for Administrators/ Teachers Travel to AEAs Workshops	$6,300/31,500	
Iowa Board of Regents (Eisenhower Funds)	$356,000/1,780,000	
School Districts (Phase III Money)	$538,000/2,690,000	

Part 2: Describe potential support for follow-up activities after NSF grants ends. Estimate amounts needed and potential sources.

It is estimated that another four million dollars will be needed to accomplish fully, the objectives of this initiative for two more years (1996-1998) beyond NSF funding. Staff development and training of four to six thousand math and science teachers will continue at an estimated cost of three million dollars. The remaining one million is needed for continued assessment and evaluation, workshops, project staff salaries, fringes, travel and subsistence.

The potential sources of funds for these activities are:

1. Annual appropriations by the Iowa legislature;
2. Business/industry contributions formalized during the implementation of the Partnership Program;
3. Phase III money as matching funds from school districts for staff development;

4. Eisenhower funds from the Board of Regents, the Area Education Agencies, local school districts and the Department of Education;
5. Grants from other federal agencies (i.e., Department of Education)

COST SHARING EXPLANATION

NARRATIVE PAGE

The financial support provided by the National Science Foundation will be supplemented by the following sources: annual appropriations by the Iowa General Assembly, private contributions from Iowa corporations and foundations, and discretionary resources available to local school districts which may be used in support of the Quality Science and Mathematics Education initiative. Additionally, resources available to the Department of Education, the Board of Regents and other participating institutions for mathematics and science will be focused on activities which support the initiative.

Appropriations for the 1992 fiscal year, beginning July 1, 1991, will be considered by the General Assembly during the 1991 legislative session. The Department of Education will request that the Governor and the General Assembly approve an annual appropriation of $1 million in support of the initiative. Key state leaders have indicated support for this appropriation (see letter of support). The duration of the appropriation would be for seven years; five years as a state match to funding providing by the National Science Foundation, and two years for follow-up activities. The state of Iowa will seek an annual contribution of $1 million from private corporations and foundations to match the state appropriation.

Local school districts and area education agencies will be asked to provide funding to supplement stipends for 16,000 participating teachers. In 1987, the state of Iowa established the Educational Excellence Program which annually provides $42 million to Iowa school districts and area education agencies for performance based pay plans and supplemental pay plans. Supplemental pay plans provide for the payment of additional salary to teachers who participate in either additional instructional work assignments or specialized training. It is expected that school districts and area education agencies will allocate a portion of these funds for math and science teachers who participate in the project. Agreements will be established between the state of Iowa and local education agencies to accomplish this objective.

Other resources available to the state for math and science education will be used to support the project. The state of Iowa currently receives $1.3 million annually from the U.S. Department of Education under the Eisenhower program. These funds are distributed to local education agencies ($900,000), higher education institutions ($350,000), and the Department of Education ($50,000) for science and math projects. To the extent possible, these resources will be focused on activities which support the initiative (see letters of support). Additionally, the Department of Education will be requesting an appropriation of $12 million over the next four years to increase the use of technology in our schools. These funds will be used to create a matching grant program for the establishment of at least one technological "classroom of the future" in each Iowa school district by 1995. This initiative will be structured to complement the Quality Science and Mathematics Education initiative.

Activities associated with Iowa's Partnership Plan also contemplate financial and in-kind contributions from businesses and schools which are involved in partnership programs. Resources which are provided for partnership activities will be in addition to the matching contributions from private corporations and foundations for the general support of the initiative.

Figure 2 is a summary of the financial contributions for a two year period (1996-1998) beyond NSF funding for completing the objectives of Iowa's statewide systemic initiative to improve mathematics and science education.

Financial Contributions Beyond NSF Support

SUMMARY

Activity	Source of Funding	Amount Year 6 1996-97	 Year 7 1997-98	Total
1. Staff Development (4000-6000 teachers)	Iowa Legislature	1,000,000	1,000.000	2,000,000
	Phase III matching funds	250,000	250,000	500,000
$3,000,000	Business/Industry	250,000	250,000	500,000
2. Salaries, fringes, travel & subsistence for project coordinators/ evaluators/instructors	Eisenhower Funds	150,000	150,000	300,000
$500,000	Grants	100,000	100,000	200,000
3. Workshops/Meetings	Business/Industry	100,000	100,000	200,000
$250,000	Eisenhower Funds	25,000	25,000	50,000
4. Materials/Supplies/ Resources $250,000	Business/Industry	125,000	125,000	250,000
TOTAL				**$4,000,000**

Figure 2

* Current and Pending Support for Research and Education in Science and Engineering

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of the proposal.

I **Name of Principal Investigator**	Source of Support	Project Title	Award Amount (or Annual Rate)	Period Covered by Award	Person-Months or % of Effort Committed to the Project			Location of Research
					ACAD	SUMM.	CAL. YR	
A *Current Support* List—if none, report none								
B *Proposals Pending* 1 List this proposal								
2 Other pending proposals, including renewal applications. If none, report none								
3 Proposals planned to be submitted in near future If none, report none								
II **Name of co-principal investigator and/or faculty associate** A __________ B __________								
III **Transfer of Support** If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.								
IV **Other agencies to which this proposal has been/will be submitted**								

USE ADDITIONAL SHEETS AS NECESSARY

* The Project Investigator/Director has no current and pending support for research and education in science and engineering. The same is true of any other participant spending a major commitment of time (six months or more per calendar year) towards this initiative.

NSF FORM 1239 (1-87)

SUMMARY OF RESULTS FROM PRIOR NSF SUPPORT

PI/PD: Dr. W. Tony Heiting NSF PROJECT #

PROJECT TITLE:

SUBMITTING INSTITUTION: Iowa Department of Education

Not applicable.

The PI/PD has not directed a prior NSF project in the last three years.

INCORPORATION OF OTHER EDUCATION PROJECTS

Iowa's colleges and universities have been aggressive in pursuing improvements in science and mathematics education over the years. In the past five years, 113 science and math education projects have been funded from a variety of sources including NSF, Title II, State Department of Education, lottery funds, and private foundations. These projects were reviewed in the context of this initiative to determine their potential impact for providing data, materials, and resources for Iowa's initiative. In many cases, models for curriculum development, problem solving, and inservice workshops have been developed and implemented that will serve as models towards accomplishing the goals and objectives of this initiative. The investigators will be asked to provide the results of their projects at a "Information Sharing Conference" prior to the implementation of Iowa' initiative. This conference will be sponsored by the Iowa Academy of Science, the Council of State Science Supervisors, and the Iowa Council of Teachers of Mathematics. Each invited investigator will be asked to state how their research findings and results could be incorporated into the implementation of Iowa's statewide systemic initiative to improve science and mathematics.

A number of on-going projects have already been identified that address the components of Iowa's initiative. These projects are summarized on the following pages along with their relevance to this initiative.

SUMMARY OF RESULTS FROM PRIOR NSF SUPPORT

Complete a copy of this form for each project funed by NSF in the last three years for which any PI/PD on this proposal was a PI/PD.

PI/PD: Dr. Jack Gerlovich	NSF PROJECT #
PROJECT TITLE: Iowa PSInet Networking	
SUBMITTING INSTITUTION: Drake University	

SUMMARY OF PROJECT

This project supported by NSF and Eisenhower funds and conducted by Drake University, will expand the math and science community network in Iowa and through out the country. PSInet will be used extensively as the main communication link in Iowa's initiative. Every effort will be made to link all key personnel involved in this initiative on the network. PSInet will also serve as the communication link with other states in disseminating information and results of Iowa' initiative during implementation.

SUMMARY OF RESULTS FROM PRIOR NSF SUPPORT

Complete a copy of this form for each project funed by NSF in the last three years for which any PI/PD on this proposal was a PI/PD.

PI/PD: Dr. James Shymansky NSF PROJECT # TEP 87-51680

PROJECT TITLE: The Science Teachers As Researchers (Star) Project

SUBMITTING INSTITUTION: University of Iowa

SUMMARY OF PROJECT

This project, conducted by the University of Iowa and supported by NSF has developed an inservice model to enhance middle school science teachers knowledge and teaching methods by involving them in classroom research activities. This model will be considered for the staff development and training of middle school teachers in this initiative.

SUMMARY OF RESULTS FROM PRIOR NSF SUPPORT

Complete a copy of this form for each project funed by NSF in the last three years for which any PI/PD on this proposal was a PI/PD.

PI/PD: Dr. Edward Pizzini NSF PROJECT # RCD 88-55145

PROJECT TITLE: Young Scholars Research Participation In Science and Engineering: Target Programs For Minority And Economically Disadvantaged

SUBMITTING INSTITUTION: University of Iowa

SUMMARY OF PROJECT

This program, sponsored by NSF and conducted by the University of Iowa will serve as a model for the active recruitment of minority and disadvantaged students. Teaching modules will be developed in the MSC from this model.

SUMMARY OF RESULTS FROM PRIOR NSF SUPPORT

Complete a copy of this form for each project funed by NSF in the last three years for which any PI/PD on this proposal was a PI/PD.

PI/PD: Dr. John Penick NSF PROJECT # TPE 90-50182

PROJECT TITLE: Iowa Scope, Sequence, And Coordination Reform Project In Science (SS & C)

SUBMITTING INSTITUTION: University of Iowa

SUMMARY OF PROJECT

The NSTA Scope, Sequence, and Coordination Project, recently funded in Iowa, will be a vital part of this systemic effort--although the thrust of that project is a focus upon 6-12 science education. However, the staffing models, the module development model, and the ties to local industries and community leaders will all provide direct experiences with collaboration among teachers, AEA staff, local and regional industries, organizations, and college facilities. We expect the curriculum modules, possible Scope and Sequence frameworks, and the Chautauqua in-service model to be valuable as we move to the MSC efforts in all K-8 classrooms in Iowa.

SUMMARY OF RESULTS FROM PRIOR NSF SUPPORT

Complete a copy of this form for each project funed by NSF in the last three years for which any PI/PD on this proposal was a PI/PD.

PI/PD: Dr. Roy Saigo	NSF PROJECT #
PROJECT TITLE: Inservice Institute For Middle/Junior High Science Teachers	
SUBMITTING INSTITUTION: University of Northern Iowa	

SUMMARY OF PROJECT

This project is funded by NSF and conducted by the University of Northern Iowa to provide summer institutes for teachers that include content, methodology, and lectures on leading-edge scientific topics. This project will be of particular interest to this initiative in providing topics and content background to include in the developing multidisciplinary teaching modules that are current and relevant to students.

SUMMARY OF RESULTS FROM PRIOR NSF SUPPORT

Complete a copy of this form for each project funed by NSF in the last three years for which any PI/PD on this proposal was a PI/PD.

PI/PD: Dr. Jack Wilkinson NSF PROJECT #

PROJECT TITLE: Teachers Teaching Teachers

SUBMITTING INSTITUTION: University of Northern Iowa

SUMMARY OF PROJECT

This project is conducted by the University of Northern Iowa and funded by NSF to significantly impact the teaching of mathematics in middle/junior high and high schools. This project has collected data on effective teaching methods that will be utilized in the staff development and training phases of this initiative.

SUMMARY OF RESULTS FROM PRIOR NSF SUPPORT

Complete a copy of this form for each project funed by NSF in the last three years for which any PI/PD on this proposal was a PI/PD.

PI/PD: Dr. Dean Hartman NSF PROJECT #

PROJECT TITLE: Iowa AEA Middle School Science Project

SUBMITTING INSTITUTION: Area Education Agency 10

SUMMARY OF PROJECT

This project, funded by Title II and NSF is conducted by Area Education Agency 10 in Cedar Rapids to provide hands-on, minds-on science activities for teachers in grades four through nine. The activities are written by Iowa classroom teachers and tested by Iowa teachers. The components of these activities will be revised to include the interrelationships of science and other disciplinary areas and may serve as sample MSC teaching modules.

SUMMARY OF RESULTS FROM PRIOR NSF SUPPORT

Complete a copy of this form for each project funed by NSF in the last three years for which any PI/PD on this proposal was a PI/PD.

PI/PD: Dr. Robert Ward NSF PROJECT.#

PROJECT TITLE: Preparation Of Elementary Mathematics and Science Teachers

SUBMITTING INSTITUTION: University of Northern Iowa

SUMMARY OF PROJECT

This is an NSF funded project conducted at the University of Northern Iowa designed to implement the effective teaching of science and mathematics in the elementary schools. The project model developed may be incorporated in this initiative in revising our teacher preparation programs in math and science. Many of the project goals such as integrating content, learning theory, and teaching strategies are consistent with this initiative. The progress, findings and results of this project will significantly expedite the revisions in our teacher preparation programs as outlined in this initiative.

SUMMARY OF PROJECTS OR GRANTS FROM OTHER FEDERAL SOURCES

SCIENCE WORKSHOPS TO TRAIN K-3 TEACHERS TO USE AN ACTIVITY-BASED SCIENCE MODEL

This project, conducted by Iowa State University, and supported by Eisenhower funds has developed interdisciplinary model activities that will be adopted as part of the MSC in this initiative.

PROJECT "UPSTAT": USING PROBLEM SOLVING IN SCIENCE TEACHING AND TRAINING

This project, conducted by the University of Iowa and supported by Eisenhower funds incorporates problem solving to integrate thinking skills as a means of encouraging women to participate in science. Although this project is just underway, it is one that will be incorporated into this initiative to meet the objective of increasing the number of women and minorities in science and math.

DEVELOPING AND IMPLEMENTING STS PROGRAMS

This program at the University of Iowa is sponsored by Eisenhower funds and conducts workshops for 6-9 grade teachers to investigate new goals, curriculum strands, teaching strategies, and plans for evaluation of science education. The STS program will be closely linked with this initiative as the STS model will be one considered in developing MSC teaching modules for the K-8 grades.

"PRISMS" DISSEMINATION PROJECT

Funded by the U.S. Department of Education and implemented by the University of Northern Iowa, this project disseminates program design/teaching strategies. The design strategies will be examined in this initiative to determine their applicability to the development of the MSC and for staff development. The PRISMS curriculum model will also be considered as an example of a successful on-going developmental curriculum.

IOWA SPACE GRANT COLLEGE CONSORTIUM

Funded by NASA and conducted at the University of Northern Iowa, this project provides interdisciplinary training, and research and recruitment, targeted to women and under-representative minorities for careers in aerospace science and technology. This new five year program will be examined as a potential resource in developing MSC teaching modules that reach under-represented groups.

PHYSICAL SCIENCE WORKSHOPS FOR TEACHERS, GRADES 3-9

This has been an annual workshop the past three years conducted by Drake University and funded by Title II money. The purpose is to provide teachers in Iowa, who are not specifically prepared to teach physical science, an indepth program to update their skills in this area. The results of these workshops have been encouraging. These results will be considered in relation to the staff development and training component of this initiative in the areas of physical and life sciences at the K-8 levels.

INFUSING TECHNOLOGY INTO MATHEMATICS AND SCIENCE EDUCATION

This project conducted by Drake University and supported by Eisenhower funds, provides training workshops for state math and science supervisors in using advanced technology in the curriculum. Iowa's initiative will use the model developed for these workshops for use by MSC developers and staff development trainers for infusing technology into the curriculum and teaching.

VITA - WILLIAM ANTON HEITING

ADDRESS

Home: 12 Liberty Bell Blvd.
Des Moines, Iowa 50317
Tel. (515) 266-8580

Office: Iowa Department of Education
Capitol Complex
Des Moines, Iowa 50319
Tel. (515) 281-3249

EDUCATION

University of Minnesota, Minneapolis, Minnesota	B.A., 1966	Major: Zoology Minor: Sociology
Wichita State University, Wichita, Kansas	M.S., 1970	Major: Science Education Minor: Biology
University of Iowa, Iowa City, Iowa	Ph.D., 1976	Major: Science Education Minor: Environmental Science

EMPLOYMENT

August, 1989
- present **Iowa Department of Education, Des Moines, Iowa.**

STATE SCIENCE CONSULTANT: Work with all K-16 schools, teachers, local school districts, Area Education Agencies, and public and private institutions in improving science education in the State of Iowa.

December, 1986
- August, 1989 **Department of Natural Resources, Energy and Geological Resources Division, Des Moines, Iowa.**

PUBLIC SERVICE EXECUTIVE: Administration and supervision of Iowa's $50 million dollar Petroleum Overcharge Program. Worked with recipient agencies and institutions in developing proposals and negotiating contracts that meet legislative directives and approval of the federal Department of Energy.

August, 1980
- December, 1986 **Iowa Energy Policy Council, Des Moines, Iowa.**

RESEARCH/EDUCATION DIRECTOR (On contract from the University of Iowa): Supervised the staff and programs in energy research and education funded by federal and state monies. These programs included the Emergency Energy Preparedness program; state Energy Extension Service program; and the state Energy Conservation program. Responsible for developing the policies and procedures for the administration of energy research grants and the implementation of the projects. Initiated and supervised a comprehensive energy education program which included the development of K-12 curriculum materials and the inservicing of over 10,000 teachers.

August, 1978
- August, 1980 **Iowa Energy Policy Council, Des Moines, Iowa.**

DIRECTOR OF ENERGY RESOURCES (On contract from the University of Iowa): Supervised the staff and programs of the state Solar Office, the state Set-A-Side program, and the state Energy Research program. The state research program administered grants and the federal Appropriate Technology program. The state Solar Office coordinated all solar activities in the state including biomass, hydro, solar research, and educational outreach programs. The state Set-A-Side program was responsible for petroleum distributions during the 1978-89 petroleum/natural gas crisis.

August, 1976
- August, 1978 **Iowa Energy Policy Council, Des Moines, Iowa**

RESEARCH DIRECTOR (On contract from the University of Iowa): Responsible for managing and coordinating federal and state funded energy research, development, and demonstration projects. This $250,000 program involved the selection, contractual negotiation, implementation, monitoring, and evaluation of 40 RD&D projects with universities, institutions, and private contractors.

August, 1966
- August, 1986 **University of Iowa, Wichita State University and Ghana, West Africa.**

TEACHING EXPERIENCE

University of Iowa, 1973-1976: Science methods instructor; supervisor of student teachers; administrative assistant to the department head; and managing editor of the Iowa Science Teachers Journal.

Wichita Schools, 1970-1973: Biology, physiology, physical science, and astronomy at the high school level.

Wichita State University, 1968-1970: Coordinator and instructor of the South Central Elementary Math and Science program.

Ghana, West Africa, 1966-1968: Chemistry, general science, and physical science instructor at African Secondary Schools.

PROFESSIONAL ORGANIZATIONS

National Science Teachers Association.
National Association for Research in Science Teaching.
Association for Supervision and Curriculum Development.
Council of State Science Supervisors.
National Association of Biology Teachers.
Association for the Education of Teachers in Science.
Iowa Academy of Science.
Iowa Science Teachers Section.
Iowa Council of State Science Supervisors.

PROFESSIONAL ACTIVITIES

President - Iowa Council of State Science Supervisors.
Member - Preparation of Elementary Math and Science Advisory Board.
Member - Business/Educator Alliance Advisory Board.
Member - Iowa Science Teachers Section Executive Board.
Member - Iowa Public Television K-12 Task Force Advisory Board.
Member - Education Committee, Iowa Academy of Science, Advisory Board.
Chairman - State Presidential Awards for Excellence in Science and Math Committee.
Member - Iowa Partners in Science Literacy Advisory Board.
Member - Governor's Advisory Board on Math and Science.
Member - Chemical Education for Public Understanding Advisory Committee.
Member - Council of State Science Supervisors.
Member - Aerospace Education Council of Iowa Advisory Committee.
Member - Iowa Academy of Science Board.
Member - Program for Women in Science and Engineering Advisory Board.

AWARDS AND DISTINCTIONS

Selected for the Teachers for West
Africa Program,
Ghana, West Africa
1966-1968

Graduate Teaching Fellowship
Wichita State University
Wichita, Kansas
1969-1970

National Science Foundation Grant
Kansas State Teachers College,
Emporia, Kansas
1973

Tuition Scholarship,
University of Iowa,
Iowa City, Iowa
1973-1976

Appointed by Governor Robert D. Ray
as Iowa's Council of State representative
to the Mid-America Solar Energy Complex,
1978-1982

Graduate Teaching Assistantship,
Science Education Center,
University of Iowa, Iowa City
1973-1976

COMMUNITY AFFILATIONS

Elected to City Council, 1983 and 1986, Pleasant Hill, Iowa.
Mayor Pro-Tem, Pleasant Hill, Iowa.
Board of Directors, Des Moines YMCA.
Chairman, Fitness, Committee, Des Moines YMCA.
Board of Directors, Des Moines Girls's Softball Association.
President, Des Moines Handball Club.
State Commissioner of Iowa - United States Handball Association.
Member, Civic Center, Des Moines.
Member, University of Iowa Alumni Club.
Board of Directors, Des Moines Metro Solid Waste Agency.
Member, Des Moines Elks Lodge.

PUBLICATIONS (last three years):

Heiting, T.W (1989), A Message from the State Science Consultant, Iowa Science Teacher's Journal.

Heiting, T.W. (1989), News for Iowa Science Educators, Science Education Newsletter, Volume 1, No. 1.

Heiting, T.W. (1989), News for Iowa Science Educators, Science Education Newsletter, Volume 1, No. 2.

Heiting, T.W. (1988), Iowa's Oil Overcharge Programs, The Iowa Conservationist.

Heiting, T.W. (1988), Energy Education Saves Energy, Iowa Energy Bulletin.

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BRIEF BIBLIOGRAPHY OF PERTINENT LITERATURE

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Anderson, J.L. (1980). A Survey of Elementary Science in Iowa. Masters Thesis, University of Northern Iowa, Cedar Falls, Iowa, 1980.

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National Council of Teachers of Mathematics. (1989). Curriculum and Evaluation Standards for School Mathematics. National Research Council, Washington, D.C.

National Research Council. (1989). Everybody Counts: A Report on the Future of Mathematics Education. National Academy Press, Washington, D.C.

National Research Council. (1988). Improving Indicators of the Quality of Science and Mathematics Education in Grades K-12. National Research Council, Washington, D.C.

National Science Board Commission on Precollege Education in Mathematics, Science, and Technology. (1983). Educating Americans for the 21st Century: A report to the American people and the national science board. Washington, D.C.: National Science Foundation.

National Council of Teachers of Mathematics. (1989). Everybody Counts: A Report to the Nation on the Future of Mathematics Education. Washington, D.C., National Research Council, 1989.

Osborne, R.J. and Wittrock, M.C. (1983). Learning Science: A Generative Process. Science Education 67 (4), 1983.

Penick, J.E., and Yager, R.E. (1988, November-December). Science Teacher Education: A program with a theoretical and pragmatic rationale. Journal of Teacher Education, 39 (6), pp. 56-64.

Project 2061. (1989). Science for All Americans. American Association for the Advancement of Science.

Reilly, D.H. (1989). A Knowledge Base for Education: Cognitive Science. Journal of Teacher Education, 40(3).

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Watson, F.G. (1988). General Education in the Sciences in Transition. Journal of College Science Teaching. Vol. XVII, No.6, May, 1988.

Yager, R.E. and Bonnstetter, R.J. (1984). Student Perceptions of Science Teachers Classes and Course Content. School Science and Mathematics, 1984.

SUPPORT LETTERS

IOWA
AREA
EDUCATION
AGENCIES

RECEIVED
OCT 0 4 1990
DEPARTMENT OF
EDUCATION

October 3, 1990

Ted Stilwill
Administrator
Division of Professional and
Administration Support
Department of Education
Grimes State Office Building
Des Moines, IA 50319

Dear Dr. Stilwill:

This letter is to lend support to the Department's efforts to secure funding from the National Science Foundation to increase the quality of science and math education through a focus on teacher preparation and professional development.

As you know, Iowa's area education agencies have been leaders in the improvement of math and science education through our network of numerous consultants in those fields. Math and science teachers are assisted by these professionals in every corner of our state. We offer the kind of personalized contact and proximity to these teachers that few other states can extend.

In addition, Iowa's area education agencies are major players in staff development. On any given day of the year, thousands of Iowa's teachers are receiving training delivered or facilitated by AEAs. We are most proud of our efforts in this arena and are looking toward an expanded future role in staff development.

For these reasons I am extending the commitment of Iowa's AEAs to cooperate fully in any way we can to improve science and math education in our state. You have our full support in your efforts to secure grant funding.

Sincerely,

R. S. Fielder

Ronald S. Fielder, Ph.D.
President
Iowa Association of AEA Administrators

jb

RICHARD J. VARN
STATE SENATOR
District Twenty-seven

HOME ADDRESS
R R #2 Box 229M
Solon, Iowa 52333
Phone: (319) 848-7533

STATE CAPITOL
Phone: (515) 281-3371

The Senate
STATE OF IOWA
Seventy-Third General Assembly
STATE HOUSE
Capitol
Des Moines, Iowa 50319

COMMITTEES

Appropriations Subcommittee
on Education, *Chair*
Appropriations
Education
Environment and Energy
Utilities
Judiciary

Charles R. Eilber
Program Director, Statewide Systemic Initiative
National Science Foundation
1800 G Street NW
Washington, D.C. 20550

Dear Mr. Eilber,

As chair of the Senate Education Appropriations Subcommittee, I am writing to express my wholehearted support for the State of Iowa's application to the National Science Foundation for the statewide math and science grant. Iowa's proposal to develop a multi-disciplinary K-8 science and mathematics curriculum and to provide staff development programs for math and science teachers in Iowa will lead to major improvements in student learning in math and science. This project can also help show the way for successful reform nationwide to help our country regain the competitive edge in these crucial curricular areas.

While I cannot speak for the General Assembly as we are not currently in session, I do offer my pledge to work for matching funds for this grant. Our track record of support for efforts such as this is excellent and I am confident that the legislature would support it. Iowans are extraordinarily supportive of education and pride themselves in being leaders in education reform and improvement.

I thank you for your thoughtful consideration of the application and look forward to seeing this project through to completion.

Sincerely,

R Varn

Richard J. Varn
State Senator

RJV:tak

SENATE DISTRICT 27
Poweshiek County, Iowa County and part of Johnson County

Amoco Corporation
200 East Randolph Drive
Post Office Box 87703
Chicago, Illinois 60680-0703
Public and Government Affairs
312-856-5671

Gene E. Cartwright
Manager, Community and Urban Affairs

October 10, 1990

Mr. Charles R. Eilber
Program Director
Statewide Systemic Initiatives-Rm 504
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550

Dear Mr. Eilber:

For the past year, Amoco Corporation has been working with the Iowa Department of Education to identify specific areas where corporate support could lead to improved education for Iowa's students. The projects we have identified complement the current proposal being submitted to the National Science Foundation for a statewide initiative in math and science. Amoco's adoption of Iowa is due to our involvement with the Business Roundtable's ten-year education commitment.

Amoco will be committing significant funding in support of projects which will augment Iowa's proposal, Quality Science and Mathematics Education: A Multidisciplinary Approach. These projects include expanding Iowa's PSInet system, a Homework Parent/Student Outreach Program, a School Attendance Outreach Program, and support for innovative curriculum materials. We believe that these and other programs, in conjunction with the proposal submitted to the NSF, will help build an understanding among young people in Iowa of the importance of math and science to their preparation for participation in tomorrow's workforce.

We look forward to our partnership with Iowa, and support the selection of their proposal for funding by the National Science Foundation.

Sincerely,

G. E. Cartwright

GEC/kdj

Marvin A. Pomerantz, President, *Des Moines*
Marvin S. Berenstein, *Sioux City*
John R. Fitzgibbon, *Des Moines*
Betty Jean Furgerson, *Waterloo*
John M. Greig, *Estherville*
Elizabeth D. Hatch, *Cedar Rapids*
James R. Tyler, *Atlantic*
Victoria A. Westenfield, *Huxley*
Mary C. Williams, *Davenport*

Iowa

State Board of Regents DES MOINES, IOWA 50319
OLD HISTORICAL BUILDING Telephone (515) 281-3934 R. WAYNE RICHEY, *Executive Director*

October 12, 1990

Mr. Charles R. Eilber
Program Director
Statewide Systemic Initiatives-Room 504
National Science Foundation
1800 G. Street NW
Washington, D.C. 20550

Dear Mr. Eilber:

I am writing to express my support for the state of Iowa's application to the National Science Foundation in response to the Program Solicitation on Statewide Systemic Initiatives in Science, Mathematics, and Engineering Education. Representatives of the Colleges of Education at each of our state universities have been involved in the development of this proposal. We are very much looking forward to working in collaboration with Iowa's private colleges, community colleges, area education agencies, the Department of Education, and elementary and secondary schools to improve the quality of math and science education. Eisenhower funds, subject to conditions established by the U. S. Department of Education, and other resources available to the universities will be used for activities in support of this initiative.

On behalf of the Iowa Board of Regents, we look forward to your favorable consideration of this application.

Sincerely,

R. Wayne Richey

R. Wayne Richey

gep/AG31/NSF.AP

STATE UNIVERSITY OF IOWA, *Iowa City* IOWA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY, *Ames* UNIVERSITY OF NORTHERN IOWA, *CEDAR FALLS*
IOWA BRAILLE AND SIGHT-SAVING SCHOOL, *Vinton* IOWA SCHOOL FOR THE DEAF, *Council Bluffs*

APPENDICES

Appendix A

Accreditation Standards for Iowa's Schools

Accreditation Standards for Iowa's Schools

A current reproduction of Chapter 12 of the Iowa Administrative Code, 11/1/89.
This reference provided by:

Department of Education
Bureau of School Administration and Accreditation
Grimes State Office Building
Des Moines, Iowa 50319-0146

CHAPTER 12
GENERAL ACCREDITATION STANDARDS
(Applicable July 1, 1989)
[Prior to 9/7/88, see Public Instruction Department(670) Ch 4]

PREAMBLE

The following standards are the minimum requirements that must be met by an Iowa public school district to be accredited. A public school district that does not maintain accreditation shall be merged by the state board of education with one or more contiguous school districts as required by Iowa Code subsection 256.11(12). A nonpublic school must meet the standards if it wishes to be designated as accredited for operation in Iowa. The standards are intended to fulfill the state's responsibility for making available an appropriate educational opportunity for each child of school age in Iowa. They are designed to ensure that each child has access to educational programs essential to the needs and abilities of the child regardless of race, sex, handicapping condition, language, socioeconomic background, or geographic location. No public school district, or a nonpublic school desiring to be accredited, is required to meet the provisions of this chapter prior to July 1, 1989.

DIVISION I
GENERAL STANDARDS

281—12.1(256) General standards.

12.1(1) *Educational units governed by standards.* These standards govern the accreditation of all prekindergarten, if offered, or kindergarten through grade twelve school districts operated by public school corporations and the accreditation, if requested, of prekindergarten or kindergarten through grade twelve schools operated under nonpublic auspices. "School" means prekindergarten, if offered, and any organizational pattern of kindergarten through grade twelve of an elementary-secondary education program. Equal opportunity in programs shall be provided to all students regardless of race, national origin, sex, or disability. Each board shall take affirmative steps to integrate students in attendance centers and courses. In order to monitor progress, district, attendance centers, and course enrollment, data shall be collected on the basis of race, national origin, sex and disability, and reviewed and updated annually.

12.1(2) *School board.* Each school or school district shall be governed by an identifiable authority which shall exercise the functions necessary for the effective operation of the school and referred to in these rules as the "board."

12.1(3) *Application for accreditation.* The board of any school or school district that is not accredited on the effective date of these standards and which seeks accreditation shall file an application with the director, department of education, on or before the first day of January of the school year preceding the school year for which accreditation is sought.

12.1(4) *Accredited schools and school districts.* Each school or school district receiving accreditation under the provisions of these standards shall remain accredited except when by action of the state board of education it is removed from the list of accredited schools maintained by the department of education in accordance with Iowa Code subsections 256.11(11) and 256.11(12).

12.1(5) *When nonaccredited.* A school or school district shall be nonaccredited on the day after the date it is removed from the list of accredited schools by action of the state board of education.

12.1(6) *Exemption request.* A board may request from the director of the department of education exemption from one or more of the requirements of the educational program specified in Iowa Code subsection 256.11(5). The request shall meet all requirements of Iowa Code subsection 256.11(8) and shall be granted only if the director determines that it is part of a planned, innovative curriculum project meeting the educational needs and interests of pupils and is broadly consistent with the intent of the educational program as defined in Iowa Code subsection 256.11(5). The director shall require an annual renewal of the exemption; any renewal of the exemption shall be at the discretion of the director.

12.1(7) *Alternative provisions for accreditation.* School districts may meet accreditation requirements through the provisions of Iowa Code sections 256.13, nonresident pupils; 273.7A, services to school districts; 279.20, superintendent—term; 280.15, joint employment and sharing; 282.7, attending in another corporation—payment; and 282.10, whole grade sharing. Nonpublic schools may meet accreditation requirements through the provisions of Iowa Code section 256.12.

DIVISION II
DEFINITIONS

281—12.2(256) Definitions. For purposes of these accreditation standards, the following definitions shall be used.

12.2(1) *Minimum school calendar and day of instruction.* Each board shall adopt a school calendar that identifies specific days for student instruction, staff development and in-service time, and time for teacher conferences. The length of the school calendar does not dictate the length of contract or employment days for individual instructional and noninstructional staff. The school calendar may be operated any time during the school year of July 1 to June 30 as defined by Iowa Code section 279.10. A minimum of 180 days of the school calendar, for school districts beginning no sooner than a day during the calendar week in which the first day of September falls, shall be used for student instruction. These days shall meet the definitions of "day of school" in subrule 12.2(2), "minimum school day" in subrule 12.2(3), and "day of attendance" in subrule 12.2(4). (Exception: A school or school district may, by board policy, excuse graduating seniors up to five days of instruction after district requirements for graduation have been met.) Of the remaining days in the school calendar, a minimum of 20 days, excluding vacation and holidays, shall be used as determined by the board for other educational purposes involving instructional and noninstructional staff.

12.2(2) *Day of school.* A day of school is a day during which the school or school district is in session and pupils are under the guidance and instruction of the instructional professional staff. School shall be considered in session during parent-teacher conferences as well as during activities such as field trips if pupils are engaged in school programs or activities under the guidance and direction of the instructional professional staff. All grade levels of the school or school district must be operated and available for attendance by all pupils. An exception is if either the elementary or secondary grades are closed for a portion of the day for activities such as staff in-service programs or parent-teacher conferences provided that this time is made up at some other point during the school calendar so as to meet the minimum of 180 days of instruction for all grade levels one through twelve. If a classroom or attendance center is closed for emergency health or safety reasons but the remainder of the school or school district is in operation, the day may be counted as a day of school.

12.2(3) *Minimum school day.* A school day shall consist of a minimum of five and one-half hours of instructional time for all grades one through twelve. The minimum hours shall be exclusive of the lunch period. Passing time between classes as well as time spent on parent-teacher conferences may be counted as part of the five and one-half hour requirement. The school or school district may record a day of school with less than the minimum instructional hours if emergency health or safety factors require the late arrival or early dismissal of pupils on a specific day; or if the total hours of instructional time for all grades one through twelve in any five consecutive school days equals a minimum of twenty-seven and one-half hours, even though any one day of school is less than the minimum instructional hours because of a staff development opportunity provided for the instructional professional staff.

12.2(4) *Day of attendance.* A day of attendance shall be a day during which a pupil was present and under the guidance and instruction of the instructional professional staff. A pupil shall not be counted in attendance during school calendar days designated by the board for certificated staff in-service programs or for parent-teacher conferences unless these are conducted outside the time required for a "minimum school day." (Note exception in subrule 12.2(2).)

12.2(5) *Enrolled pupil.* A pupil shall be considered enrolled after registering with the school or school district and taking part in the educational program.

12.2(6) *Kindergarten program.* A kindergarten program complying with the educational program description in subrule 12.5(2) shall be operated by a school district. A nonpublic school is not required to offer kindergarten in order to be accredited. The number of instructional days within the school calendar and the length of the school day for kindergarten shall be defined by the board.

DIVISION III
ADMINISTRATION

281—12.3(256) Administration. The following standards shall apply to the administration of accredited schools and school districts.

12.3(1) *Board records.* Each board shall adopt by written policy a system for maintaining accurate records. The system shall provide for recording and maintaining the minutes of all board meetings, coding all receipts and expenditures, and recording and filing all reports required by the Iowa Code or requested by the director of the department of education. Financial records of school districts shall be maintained in a manner as to be easily audited according to accepted accounting procedures.

12.3(2) *Policy manual.* The board shall develop and maintain a policy manual which provides a codification of its policy actions with the adoption date, the review date, and any revision date of each. Policies shall be reviewed at least every three years to ensure relevance to current practices and compliance with the Iowa Code, administrative rules and decisions, and court decisions.

12.3(3) *Needs assessment, statement of philosophy, and long-range plans.* The board, in compliance with Iowa Code section 280.12 and as a standard for accreditation, shall adopt and implement a process for conducting an ongoing needs assessment for the school or school district. Information obtained from this process shall be used by the board, in conjunction with other data, to establish and update both long- and short-range plans which include specific goals for meeting the identified needs. The purpose of the assessment process is twofold: first, to assist the board in developing and evaluating a statement of philosophy for the school or school district; and second, to determine the areas of student performance, knowledge, and attitudes which are judged to be most crucial in meeting school or district goals. This process, for school districts, shall comply with Iowa Code section 280.18 requiring the adoption of goals to improve student achievement and performance. As part of its assessment the board shall develop a process for communicating with business, industry, labor, and higher education regarding their expectations for adequate student preparation.

The statement of philosophy shall describe the board's beliefs about topics which shall include, but need not be limited to, the nature of learning, the purpose of the school or school district, the scope of educational experiences that the school or school district should provide, the nature of its learners, and a description of a desirable learning atmosphere.

While there are various procedures or models that may be used in conducting a needs assessment, the following basic steps shall be included. School goals shall be identified and stated in terms of what learners should be able to perform as a result of their schooling. The board shall determine which of these goals represent learning that would help the majority of the students in each course assume responsibilities as citizens, parents, and wage earners. Such identified goals shall be called basic skills and should be given the highest priority. School staff, students, parents, and community members shall recommend courses to be offered above requirements established by subrules 12.5(1) to 12.5(5) and within the optional areas described in subrule 12.5(5), pargraphs *"g," "h,"* and *"i."* Recommendations of this committee shall primarily reflect both the identified needs and resources of the school or school district. Assessment procedures, including those persons responsible for assessment, shall be identified for goals in the basic skills areas, and performance criteria shall be established and reviewed.

In identifying school goals, specific consideration shall be given to the five-year plan for the achievement of educational goals in Iowa developed by the state board of education as required by Iowa Code subsection 256.7(4).

As part of its needs assessment policy the board shall include provisions for keeping its various publics regularly informed of its policies, procedures, programs, and planning for the school or school district. This policy shall ensure involvement and consultation with students, parents, teachers, administrators, and representatives from the community in developing the various processes required by Iowa Code section 280.12.

12.3(4) *Personnel evaluation.* Each board shall adopt a performance evaluation process for school personnel. Personnel evaluation processes of school districts shall conform to Iowa Code sections 260.33 and 279.14.

12.3(5) *Instructional time audit.* The board shall by adopted policy require its administration to provide an audit of the availability of instructional time for students. Considerations in an audit shall include, but need not be limited to, the patterns of employment and assignment of instructional professional staff; the relationship of the school organization and instructional methods to the availability of instructional time; identification of the responsibility for organizing and managing the instructional program, with specific attention to the effect of curriculum sequencing and integration on instructional time availability; and the effect of cocurricular and extracurricular activity programs on availability of instructional time.

The administration shall provide an annual report to the board on the availability of instructional time for students.

12.3(6) *Student records.* Each board shall require its administrative staff to establish and maintain a system of pupil records. This system shall include for each pupil a permanent office record and a cumulative record.

The permanent office record shall serve as a historical record of official information concerning the pupil's education. At a minimum it should reflect evidence of attendance and educational progress, provide an official transcript, have all base data for use in planning to meet educational needs, and provide all data for official school reports. This record is to be permanently maintained and stored in a fire-resistant safe or vault.

The cumulative record shall provide a continuous and current record of significant information on progress and growth. It should reflect information such as courses taken, scholastic progress, school attendance, physical and health record, experiences, interests, aptitudes, attitudes, abilities, honors, extracurricular activities, part-time employment, and future plans. It is the "working record" used by the instructional professional staff in understanding the pupil. At the request of a receiving school or school district, a copy of the cumulative record shall be sent to officials of that school when a pupil transfers.

The board shall adopt a policy concerning the accessibility and confidentiality of pupil records that complies with the provisions of the federal Family Educational Rights and Privacy Act of 1974, as amended, and Iowa Code chapter 22.

12.3(7) *Standards for graduation.* Each board providing a program through grade twelve shall adopt a policy establishing the requirements students must meet for high school graduation. This policy shall make provision for early graduation and shall be consistent with these standards and the Iowa Code.

12.3(8) *Student responsibility and discipline.* The board shall adopt student responsibility and discipline policies. In developing or revising such policies, the board shall involve parents, students, instructional and noninstructional professional staff, and community members. Student responsibility and discipline policies shall relate to the educational purposes of the school or school district. The policies shall include, but need not be limited to, attendance; use of tobacco and the use or possession of alcoholic beverages or any controlled substance; violent, destructive, and seriously disruptive behavior; suspension, expulsion, emergency removal, corporal punishment, and physical restraint; out-of-school behavior; participation in extracurricular activities; academic progress; and citizenship.

In developing and applying student responsibility and discipline policies, the board shall ensure due process rights for students and parents. In some instances this may require developing separate policies for students who have been identified as requiring special education programs and services.

The board shall also consider the potential of a disparate impact on students by virtue of race, sex, disability, or national origin.

The board shall publicize its support of these policies; its support of the staff in enforcing them; and the staff's accountability for implementing them.

12.3(9) *Health services.* The board shall adopt a policy for the implementation of a school health services program. The program shall be designed to help each student protect, improve, and maintain physical, emotional, and social well-being.

Areas to be considered in the development of a policy could include, but not necessarily be limited to: environmental health and safety; emergency health procedures and responsibilities; health promotion; communicable disease prevention and control; staffing for the school health program; administering of prescription medication; acute or chronic health problems; and health assessment and screening; and record keeping and program evaluation.

12.3(10) *Audit of school funds.* This standard applies only to public school districts. The results of the annual audit of all public school district funds conducted by the state auditor or a private auditing firm shall be made part of the official records of the board.

12.3(11) *School system organizational structure.* The board shall officially adopt an organizational structure for the school(s) under its jurisdiction. This action shall be recorded in its minutes.

12.3(12) *Report on nonpublic school instruction.* Between September 1 and October 1 of each year the secretary of each public school district board shall request from each nonpublic school located within its boundaries a report of private school instruction as required by Iowa Code section 299.3. Each nonpublic school shall submit the required report in duplicate. The secretary of the public school board shall send one copy to the board secretary of the area education agency within which the public school district is located.

Each nonpublic school shall send to each public school district from which it receives pupils a list of the pupils of compulsory school age enrolled in the nonpublic school who are residents of that district. This list shall include the name, grade, date of birth, name of parent or guardian, and location of the pupil's residence.

DIVISION IV
SCHOOL PERSONNEL

281—12.4(256) School personnel. Certificate and endorsement standards required in this rule relate to certificates and endorsements issued by the state board of education. The following standards shall apply to personnel employed in accredited schools.

12.4(1) *Instructional professional staff.* Each person who holds a certificate endorsed for the service for which that person is employed shall be eligible for classification as a member of the instructional professional staff.

12.4(2) *Noninstructional professional staff.* A person who holds a statement of professional recognition, including but not limited to a physician, dentist, nurse, speech therapist, or a person in one of the other noninstructional professional areas designated by the state board of education, shall be eligible for classification as a member of the noninstructional professional staff.

12.4(3) *Basis for approval of professional staff.* Each member of the professional staff shall be classified as either instructional or noninstructional. An instructional professional staff member shall be regarded as approved when holding either an appropriate certificate with endorsement or endorsements, or a certificate with an approval statement, indicating the specific teaching assignments that may be given. A noninstructional professional staff member shall be regarded as approved when holding a statement of professional recognition for the specific type of noninstructional professional school service for which employed.

12.4(4) *Required administrative personnel.* Each board that operates both an elementary school and a secondary school shall employ as its executive officer and chief administrator a person who holds a certificate endorsed for service as a superintendent. The board of a school district may meet this requirement by contracting with its area education agency for "superintendency services" as provided by Iowa Code section 273.7A. The individual employed or contracted for as superintendent cannot also serve as a principal in that school or school district. Boards of school districts may jointly employ a superintendent, provided such arrangements comply with the provisions of Iowa Code subsection 279.23(4).

The effective date of a superintendent not serving as a principal in the school or school district is delayed until July 1, 1990. A school or school district unable to meet the requirement stated in this subrule may file a written request with the department of education that the department waive the requirement until July 1, 1991. The request must be filed with the department of education by January 1, 1990, and shall include the following information: description of school system organization structure and administrative staff; reason(s) the school or school district is not able to meet the standard as of July 1, 1990; efforts undertaken to meet the standard including but not limited to attempts to employ staff, share staff, get current staff qualified and other efforts; specific actions proposed by school or school district for meeting the standard including proposed timelines for compliance. A request for waiver must be signed by the board president and the chief administrator.

The department of education shall grant the waiver if it is able to determine from the information filed that the school or school district has made a good faith effort to meet the standard and that there is a reasonable expection that the standard will be met by July 1, 1991.

12.4(5) *Staffing policies—elementary schools.* The board operating an elementary school shall develop and adopt staffing policies designed to attract, retain, and effectively utilize competent personnel. Each board operating an elementary school shall employ at least one elementary principal. This position may be combined with that of secondary principal or with a teaching assignment at the elementary or secondary level, provided the individual holds the proper certificates and endorsements. This position cannot be combined with that of superintendent. See effective date and waiver information provided in subrule 12.4(4).

When grades seven and eight are part of an organized and administered junior high school, the staffing policies adopted by the board for secondary schools shall apply. When grades seven and eight are part of an organized and administered middle school, the staffing policies adopted by the board for elementary schools shall apply.

12.4(6) *Staffing policies—secondary schools.* The board operating a secondary school shall develop and adopt staffing policies designed to attract, retain, and effectively utilize competent personnel. Each board operating a secondary school shall employ at least one secondary principal. This position may be combined with that of elementary principal or with a teaching assignment at the elementary or secondary level, provided the individual holds the proper certificates and endorsements. This position cannot be combined with that of superintendent. See effective date and waiver information provided in subrule 12.4(4).

12.4(7) *Principal.* A principal shall be defined as a member of the instructional professional staff who holds a certificate endorsed for the type of position in which employed. Under the supervision of the superintendent and pursuant to rules and policies of the board, the principal serves as site manager and instructional leader of the attendance center or centers to which assigned; supervises the process and content involved in the delivery of educational and instructional services; coordinates the development of the budget for the attendance center or centers for which responsible; supervises and evaluates all assigned certificated and noncertificated staff; submits recommendations to the administration regarding the appointment, assignment, promotion, transfer, and dismissal of all personnel assigned to the attendance center or centers for which responsible; assists in developing and implementing board policy; and supervises a student activities program and assists in its development.

12.4(8) *Teacher.* A teacher shall be defined as a member of the instructional professional staff who holds a certificate endorsed for the type of position in which employed. A teacher diagnoses, prescribes, evaluates, and directs student learnings in terms of the school's objectives, either singly or in concert with other professional staff members; shares responsibility with the total professional staff for developing educational procedures and student activities to be used in achieving the school's objectives; supervises educational aides who assist in serving students for whom the teacher is responsible; and evaluates or assesses student progress during and following instruction in terms of the objectives sought, and uses this information to develop further educational procedures.

12.4(9) *Educational aide.* An educational aide shall be defined as an employee or volunteer who, in the presence or absence of an instructional professional staff member but under the direction, supervision, and control of the instructional professional staff, supervises students on a monitorial or service basis; and works with students in a supportive role under conditions determined by the instructional professional staff responsible for the students, but not as a substitute for or a replacement of functions and duties of a teacher as established in subrule 12.4(8).

During the initial year of employment, an educational aide shall complete an in-service training program approved by the board as provided in subrule 12.7(1).

12.4(10) *Record of certificate or statement of professional recognition.* The board shall require each administrator, teacher, support service staff member, and noninstructional professional staff member on its staff to supply evidence that each holds a certificate or statement of professional recognition which is in force and valid for the type of position in which employed.

12.4(11) *Record required regarding teacher and administrative assignments.* The board shall require its superintendent or other designated administrator to maintain a file for all regularly employed members of the instructional professional staff, including substitute teachers. The file shall consist of complete official transcripts of the preparation of these staff members and their legal certificates or copies thereof showing that they are eligible for the position in which employed. The official shall also maintain on file a legal certificate or statement of professional recognition as defined in subrule 12.4(2) for each member of the noninstructional professional staff. These records shall be on file at the beginning of and throughout each school year and shall be updated annually to reflect all professional growth.

On December 1 of each year, the official shall verify to the department of education the certification and endorsement status of each member of the instructional and administrative staff. This report shall be on forms provided by the department of education and shall identify all persons holding conditional authorizations and their specific assignment(s) with the conditional authorization(s).

12.4(12) *Nurses.* Each board that employs a nurse shall require a current license to be filed with the superintendent or other designated administrator as specified in subrule 12.4(10).

12.4(13) *Prekindergarten staff.* Prekindergarten teachers shall hold a certificate valid for the prekindergarten level. The board shall employ personnel as necessary to provide effective supervision and instruction in the prekindergarten program.

12.4(14) *Physical examination.* Except as otherwise provided in 281—43.15, the local board shall require each employee to file with it certification of fitness to perform the tasks assigned which shall be in the form of a written report of a physical examination, including a check for tuberculosis, by a licensed physician and surgeon, osteopathic physician and surgeon, osteopath, or qualified doctor of chiropractic. A report shall be filed at the beginning of service and at three-year intervals.

Each doctor of chiropractic licensed as of July 1, 1974, shall affirm on each certificate of physical examination that the affidavit required by Iowa Code section 151.8 is on file with the Iowa board of chiropractic examiners.

12.4(15) *Support staff.* The board shall develop and implement procedures for the use of educational support staff to augment classroom instruction and to meet individual student needs. These staff members may be employed by the board or by the area education agency.

DIVISION V
EDUCATION PROGRAM

281—12.5(256) Education program. The following education program standards shall be met by schools and school districts for accreditation with the start of the 1989-1990 school year.

12.5(1) *Prekindergarten program.* If a school offers a prekindergarten program, the program shall be designed to help children to work and play with others, to express themselves, to learn to use and manage their bodies, and to extend their interests and understanding of the world about them. The prekindergarten program shall relate the role of the family to the child's developing sense of self and perception of others. Planning and carrying out prekindergarten activities designed to encourage cooperative efforts between home and school shall focus on community resources. A prekindergarten teacher shall hold a certificate certifying that the holder is qualified to teach in prekindergarten. A nonpublic school which offers only a prekindergarten may, but is not required to, seek and obtain accreditation.

12.5(2) *Kindergarten program.* The kindergarten program shall include experiences designed to develop healthy emotional and social habits and growth in the language arts and communication skills, as well as a capacity for the completion of individual tasks, and protect and increase physical well-being with attention given to experiences relating to the development of life skills and human growth and development. A kindergarten teacher shall be certificated to teach in kindergarten. An accredited nonpublic school must meet the requirements of this subsection only if the nonpublic school offers a kindergarten program.

12.5(3) *Elementary program, grades 1-6.* The following areas shall be taught in grades one through six: English-language arts, social studies, mathematics, science, health, human growth and development, physical education, traffic safety, music, and visual art.

In implementing the elementary program standards, the following general curriculum definitions shall be used.

a. English-language arts. English-language arts instruction shall include the following communication processes: speaking; listening; reading; writing; viewing; and visual expression and nonverbal communication. Instruction shall incorporate language learning and creative, logical, and critical thinking. The following shall be taught: oral and written composition; communication processes and skills, including handwriting and spelling; literature; creative dramatics; and reading.

b. Social studies. Social studies instruction shall include citizenship education, history, and social sciences. Democratic beliefs and values, problem-solving skills, and social and political participation skills shall be incorporated. Instruction shall encompass geography, history of the United States and Iowa, and cultures of other peoples and nations. American citizenship, including the study of national, state, and local government; and the awareness of the physical, social, emotional and mental self shall be infused in the instructional program.

c. Mathematics. Mathematics instruction shall include problem solving; geometry; measurement; appropriate computational skills, including mental arithmetic; reasonableness of results; reading, interpreting, and constructing tables, charts, and graphs; estimation; and the use of calculators as standard tools in problem solving.

d. Science. Science instruction shall include life, earth, and physical science and shall incorporate hands-on process skills; scientific knowledge; application of the skills and knowledge to students and society; conservation of natural resources; and environmental awareness.

e. Health. Health instruction shall include personal health; food and nutrition; environmental health; safety and survival skills; consumer health; family life; substance abuse and nonuse, encompassing the effects of alcohol, tobacco, drugs, and poisons on the human body; human sexuality, self-esteem, stress management, and interpersonal relationships; emotional and social health; health resources; and prevention and control of disease, and the characteristics of communicable diseases, including acquired immune deficiency syndrome.

f. Physical education. Physical education instruction shall include movement experiences and body mechanics; fitness activities; rhythmic activities; stunts and tumbling; simple games and relays; sports skills and activities; and water safety.

g. Traffic safety. Traffic safety instruction shall include pedestrian safety; bicycle safety; auto passenger safety; school bus passenger safety; seat belt use; substance education; and the application of legal responsibility and risk management to these concepts.

h. Music. Music instruction shall include skills, knowledge, and attitudes and shall include singing and playing music; listening to and using music; reading and writing music; recognizing the value of the world's musical heritage; respecting individual musical aspirations and values; and preparing for consuming, performing, or composing.

i. Visual art. Visual art instruction shall include perceiving, comprehending, and evaluating the visual world; viewing and understanding the visual arts; developing and communicating imaginative and inventive ideas; and making art.

12.5(4) *Junior high program, grades 7 and 8.* The following shall be taught in grades seven and eight: English-language arts, social studies, mathematics, science, health, human growth and development, physical education, music, and visual art.

In implementing the junior high program standards, the following general curriculum definitions shall be used.

a. English-language arts. Same definition as in subrule 12.5(3)*"a"* with the exclusion of handwriting.

b. Social studies. Social studies instruction shall include citizenship education, history and social sciences. Democratic beliefs and values, problem-solving skills, and social and political participation skills shall be incorporated. Instruction shall encompass history, economics, geography, government including American citizenship, behavioral sciences, and the cultures of other peoples and nations. Strategies for continued development of positive self-perceptions shall be infused.

c. Mathematics. Same definition as in subrule 12.5(3)*"c"* with the addition of mental arithmetic through the real number system; ratio proportion, and precent.

d. Science. Same definition as in subrule 12.5(3)*"d."*

e. Health. Health instruction shall include personal health; food and nutrition; environmental health; safety and survival skills; consumer health; family life; substance abuse and nonuse, encompassing the effects of alcohol, tobacco, drugs, and poisons on the human body; human sexuality, self-esteem, stress management, and interpersonal relationships; emotional and social health; health resources; and prevention and control of disease and the characteristics of communicable diseases, including sexually transmitted diseases and acquired immune deficiency syndrome.

f. Physical education. Physical education shall include the physical fitness activities that increase cardiovascular endurance, muscular strength, and flexibility; sports and games; tumbling and gymnastics; rhythms and dance; water safety; leisure and lifetime activities.

g. Music. Same definition as in subrule 12.5(3)*"h"* with the addition of using music as an avocation or vocation.

h. Visual art. Same definition as in subrule 12.5(3)*"i"* with the addition of using visual arts as an avocation or vocation.

12.5(5) *High school program, grades 9–12.* In grades nine through twelve a unit is a course or equivalent related components or partial units taught throughout the academic year as defined in subrule 12.5(18). The following shall be offered and taught as the minimum program: English-language arts, six units; social studies, five units; mathematics, six units as specified in subrule 12.5(5)*"c"*; science, five units; health, one unit; physical education, one unit; fine arts, three units; foreign language, four units; and vocational education, five units as specified in subrule 12.5(5)*"i."*

In implementing the high school program standards, the following curriculum standards shall be used.

a. English-language arts (six units). English-language arts instruction shall include the following communication processes: speaking; listening; reading; writing; viewing; and visual expression and nonverbal communication. Instruction shall incorporate language learning and creative, logical, and critical thinking. The program shall encompass communication processes and skills; written composition; speech; debate; American, English, and world literature; creative dramatics; and journalism.

b. Social studies (five units). Social studies instruction shall include citizenship education, history, and the social sciences. Instruction shall encompass the history of the United States and the history and cultures of other peoples and nations including the analysis of persons, events, issues, and historical evidence reflecting time, change, and cause and effect; an overview of American government through the study of the United States Constitution, the federal system of government, and the structure and relationship between the national, state, county, and local governments; and voter education including instruction in statutes and procedures, voter registration requirements, the use of paper ballots and voting machines in the election process, and the method of acquiring and casting an absentee ballot. Economics shall include comparative and consumer studies in relation to the market and command economic systems. Geography shall include the earth's physical and cultural features, their spatial arrangement and interrelationships, and the forces that affect them. Sociology, psychology, and anthropology shall include the scientific study of the individual and group behavior(s) reflecting the impact of these behaviors on persons, groups, society, and the major institutions in a society. Democratic beliefs and values, problem-solving skills, and social and political skills shall be incorporated. All students in grades nine through twelve must, as a condition of graduation, complete instruction in American history and the governments of Iowa and the United States.

c. Mathematics (six units). Mathematics instruction shall include:

(1) Two units of general mathematics, encompassing components in problem solving; geometry; measurement; appropriate computational skills, incorporating mental arithmetic through the real number system; ratio, proportion, and percent; reasonableness of results; reading, interpreting, and constructing tables, charts, and graphs; estimation; applications of mathematics; quantitative literacy; and the use of calculators and computers as standard tools in problem solving.

(2) Four units of a sequential mathematics program which would serve as prerequisites to postsecondary educational programs. The program shall include algebraic, geometric, trigonometric, and finite mathematical concepts; problem solving; applications of mathematics; reasonableness of results; estimation and mental calculations; and the use of calculators and computers as standard tools in problem solving.

d. Science (five units). Science instruction shall include biological, earth, and physical science, including physics and chemistry. Full units of chemistry and physics shall be taught but may be offered in alternate years. All science instruction shall incorporate hands-on process skills; scientific knowledge; the application of the skills and knowledge to students and society; conservation of natural resources; and environmental awareness.

e. Health (one unit). Health instruction shall include personal health; food and nutrition; enviromental health; safety and survival skills; consumer health; family life; human growth and development; substance abuse and nonuse; emotional and social health; health resources; and prevention and control of disease, including sexually transmitted diseases and acquired immune deficiency syndrome, current crucial health issues, human sexuality, self-esteem, stress management, and interpersonal relationships.

f. Physical education (one unit). Physical education shall include the physical fitness activities that increase cardiovascular endurance, muscular strength and flexibility; sports and games; tumbling and gymnastics; rhythms and dance; water safety; leisure and lifetime activities.

All physically able students shall be required to participate in the program for a minimum of one-eighth unit during each semester they are enrolled except as otherwise provided in this paragraph. A twelfth-grade student may be excused from this requirement by the principal of the school in which the student is enrolled under one of the following circumstances:

(1) The student is enrolled in a cooperative, work-study, or other educational program authorized by the school which requires the student's absence from the school premises during the school day.

(2) The student is enrolled in academic courses not otherwise available.

Students in grades nine through eleven may be excused from the physical education requirement in order to enroll in academic courses not otherwise available to the student if the board of directors of the school district in which the school is located, or the authorities in charge of the school, if the school is a nonpublic school, determine that students from the school may be permitted to be excused from the physical education requirement.

A student may be excused by the principal of the school in which the student is enrolled, in consultation with the student's counselor, for up to one semester, trimester, or the equivalent of a semester or trimester, per year if the parent or guardian of the student requests in writing that the student be excused from the physical education requirement. The student seeking to be excused from the physical education requirement must, at some time during the period for which the excuse is sought, be a participant in an organized and supervised athletic program which requires at least as much time of participation per week as one-eighth unit of physical education.

The student's parent or guardian must request the excuse in writing. The principal shall inform the superintendent that the student has been excused.

g. Fine arts (three units). Fine arts instruction shall include at least two of the following:

(1) Dance. Dance instruction shall encompass developing basic movement skills; elementary movement concepts; study of dance forms and dance heritage; participating in dance; and evaluating dance as a creative art; and using dance as an avocation or vocation.

(2) Music. Music instruction shall include skills, knowledge, and attitudes *and the singing* and playing of music; listening to and using music; reading and writing music; recognizing the value of the world's musical heritage; respecting individual musical aspirations and values; preparing for consuming, performing, or composing; and using music as an avocation or vocation.

(3) Theatre. Theatre instruction shall encompass developing the internal and external resources used in the theatre process; creating theatre through artistic collaboration; relating theatre to its social context; forming aesthetic judgments; and using theatre as an avocation or vocation.

(4) Visual art. Visual art instruction shall include developing concepts and values about natural and created environments; critiquing works of art; evaluating relationships between art and societies; analyzing, abstracting, and synthesizing visual forms to express ideas; making art; and using visual art as an avocation or vocation.

h. Foreign language (four units). The foreign language program shall be a four-unit sequence of uninterrupted study in at least one language. Foreign language instruction shall include listening comprehension appropriate to the level of instruction; rateable oral proficiency; reading comprehension appropriate to the level of instruction; writing proficiency appropriate to the level of instruction and cultural awareness.

All high schools shall offer and teach the first two units of the sequence. The third and fourth units must be offered. However, the department of education may, on an annual basis, waive the third and fourth unit requirements upon the request of the board. The board must document that a certificated teacher was employed and assigned a schedule that would have allowed students to enroll, that the class was properly scheduled, that students were aware of the course offerings, and that no students enrolled.

i. Vocational education (five units). Five units of occupational education subjects, which may include, but are not limited to programs, services, and activities which prepare students for employment in office and clerical, trade and industrial, consumer and homemaking, agriculture, distributive, and health occupations.

12.5(6) *Physical education and health courses exemption.* A pupil shall not be required to enroll in either physical education or health courses if the pupil's parent or guardian files a written statement with the school principal that the course conflicts with the pupil's religious beliefs.

12.5(7) *Career education.* The board shall provide a comprehensive career education program. Curricular and cocurricular teaching and learning experiences from the prekindergarten level through grade twelve shall be provided for all students. The career education program shall be infused into the total education program. The program shall include, but need not be limited to, awareness of self in relation to others and the needs of society; exploration of employment opportunities; experiences in personal decision making; and experiences to help students integrate work values and work skills into their lives. In the implementation of this standard, the board shall comply with Iowa Code section 280.9.

12.5(8) *Board of directors' responsibility for ensuring multicultural, nonsexist approaches to educational programs.* This standard applies only to public school districts. The board shall establish a policy to ensure the school district is free from discriminatory practices in its educational programs. In developing or revising this policy, parents, students, instructional and noninstructional staff, and community members shall be involved. In addition, each board shall adopt a written plan, to be evaluated and updated at least every five years, for achieving and maintaining a multicultural, nonsexist educational program. A copy of the plan shall be on file in the administrative office of the district. The plan shall include:

a. Multicultural approaches to the educational program. These shall be defined as processes which foster knowledge of, respect and appreciation for, the historical and contemporary contributions of diverse cultural groups to society. Special emphasis shall be placed on Asian Americans, Black Americans, Hispanic Americans, American Indians, and the handicapped. The program shall provide equal opportunity for all participants regardless of race, color, age, national origin, religion, or handicap.

b. Nonsexist approaches to the educational program. These shall be defined as processes which foster knowledge of and respect and appreciation for the historical and contemporary contributions of men and women to society. The program shall reflect the wide variety of roles open to both men and women and shall provide equal opportunity to both sexes.

The plan shall also include specific goals and objectives, with implementation timelines for each component of the educational program; specific provisions for the infusion of multicultural, nonsexist concepts into each area of the curriculum developed under the provisions of subrule 12.5(14); a description of the in-service activities planned for all staff members on multicultural, nonsexist education; and evidence of systematic input by men and women, minority groups, and the handicapped in developing and implementing the plan. In schools where no minority students are enrolled, minority group resource persons shall be utilized at least annually. A description of a periodic, ongoing system to monitor and evaluate the plan shall also be included.

12.5(9) *Special education.* The board of each school district shall provide special education programs and services for its resident children which comply with rules of the state board of education implementing Iowa Code chapters 256, 273, 280, and 281.

12.5(10) *Technology in the curriculum.* The board shall adopt a plan for the efficient and effective use of technology in the instructional program. The plan shall provide for the understanding and use of current technology by staff and students and shall include a procedure to review the district's utilization of technology as a teaching and learning tool.

12.5(11) *Global education.* The board shall adopt a plan which incorporates global perspectives into all areas and levels of the educational program so that students have the opportunity to acquire a realistic perspective on world issues, problems, and prospects for an awareness of the relationship between an individual's self-interest and the concerns of people elsewhere in the world. The plan shall include procedures for a review of its effectiveness.

12.5(12) *Provisions for gifted and talented students.* The board shall have a program to meet the needs of gifted and talented students. The program shall include valid and systematic procedures, employing multiple criteria, for identifying gifted and talented students including ethnic and language diverse students if such students are enrolled; provisions for curricular programming to meet the needs of identified gifted and talented students; support services, including materials and staff, to ensure that a qualitatively differentiated program is provided; and a procedure for annual review and evaluation for the purpose of program improvement.

12.5(13) *Provisions for at-risk students.* The board shall have a plan to identify and provide special assistance to students who have difficulty mastering the language, academic, cultural, and social skills necessary to reach the educational levels of which they are capable. The plan shall accommodate students whose aspirations and achievement may be negatively affected by sterotypes linked to race, national origin, language background, gender, income, family status, and disability.

The plan shall include strategies for identifying at-risk students. These objectives shall be translated into performance objectives for all school personnel. The plan shall also include provisions for in-service training for school personnel; strategies and activities for involving and working with parents; provisions for monitoring the behavioral, social, and academic improvement of at-risk students; provisions for appropriate counseling services; strategies for coordinating school programs and community-based support services; and maintenance of integrated educational environments in compliance with federal and state nondiscrimination legislation.

12.5(14) *Educational program defined.* The educational program is the entire offering of the school, including out-of-class activities and the sequence of subjects and activities. It is also referred to as the program of studies and activities.

12.5(15) *Curriculum defined.* Curriculum is all pupil experiences that take place under the guidance of the school. It describes both the school experiences of an individual pupil and the arrangement of a cluster of courses to be taken by groups of pupils having a common objective.

12.5(16) *Curriculum development, review, and refinement.* The board shall adopt a policy outlining its procedures for developing, implementing, and evaluating its total curriculum. Each curriculum area shall have goals; suggested instructional activities, materials, and content; and expected student outcomes for each level of instruction. The policy shall identify valid, bias-free student assessment procedures and the process for monitoring student progress.

This policy shall include procedures and timelines for reviewing each instructional program, with attention given to interdisciplinary teaching of higher order thinking skills, learning skills, and communication skills.

12.5(17) *Educational program form and content.* The educational program, as adopted by the board, shall set forth the administrative measures and the sequence of learning situations which provide pupils with well-articulated, developmental learning experiences from the date of school entrance until high school graduation.

12.5(18) *Unit.* A unit is a course which meets one of the following criteria: It is taught for at least 200 minutes per week for 36 weeks; it is taught for the equivalent of 120 hours of instruction; or it is an equated requirement as a part of an innovative program filed as prescribed in subrule 12.1(6). A fractional unit shall be calculated in a manner consistent with this standard. Multiple section courses taught at the same time in a single classroom situation by one teacher do not meet this unit definition for the assignment of a unit of credit with the exception that the third and fourth years of a foreign language may be taught at the same time by one teacher in a single classroom situation each yielding a unit of credit.

12.5(19) *Credit.* A student shall receive a credit or a partial credit upon successful completion of a course which meets one of the criteria in subrule 12.5(18). The board may award credit on a performance basis through the administration of an examination, provided the examination covers the content ordinarily included in the regular course.

12.5(20) *Subject offering.* A subject shall be regarded as offered when the teacher of the subject has met the approval standards of the state board of education for that subject; instructional materials and facilities for that subject have been provided; and pupils have been informed, based on their aptitudes, interests, and abilities, about possible value of the subject.

A subject shall be regarded as taught only when pupils are instructed in it in accordance with all applicable standards outlined herein. Subjects which the law requires schools to offer and teach shall be made available during the school day as defined in subrules 12.2(2), 12.2(3), and 12.2(4).

12.5(21) *Guidance program.* Each board operating a prekindergarten through grade twelve or kindergarten through grade twelve program shall provide an articulated sequential elementary-secondary guidance program to assist students with their personal, educational, and career development. Boards operating less than a full elementary-secondary program shall provide a sequential guidance program covering all grade levels operated. The program shall involve not only counselors but also instructional and noninstructional staff, students, parents, and community members. Facilities offering both visual and auditory privacy for counseling shall be provided. Properly certificated staff shall be employed at all program levels.

Schools and school districts unable to meet the requirements of this rule as of July 1, 1989, may file a written request with the department of education seeking waiver of the requirement until July 1, 1990. The request must be filed with the department of education by January 1, 1989, and shall include the following information: description of the current guidance program and staff; reason(s) the school or school district is not able to meet the standard including, but not limited to, attempts to employ staff, share staff, or actions to have current staff become qualified; any other issues the school or school district feels justify the request for waiver; and specific actions proposed for meeting the standard including proposed timelines for compliance. Not later than January 1, 1990, the school or school district may request a one-year extension of the waiver for the school year beginning July 1, 1990.

The department of education shall grant the waiver, or a one-year extension of a previously approved waiver, if it is able to determine from the information filed that the school or school district has made a good faith effort to meet the standard and that there is a reasonable expectation that the standard will be met within the timeline established by the school or school district.

If a waiver is approved, the school or school district shall, for the period of the waiver or its extension, be in compliance with the requirements of Iowa Code section 256.11, subsection 9A.

12.5(22) *School media center and required staff.* The board shall establish and operate a media services program to support the total curriculum. Each attendance center shall have a media center except that attendance centers sharing a physical facility could have a single media center. The board shall adopt a policy and procedure for selection, replacement, gift acceptance, weeding, and reconsideration of school media center and text materials. The collection shall foster a nonsexist, multicultural approach for curriculum studies and individual interests. The budget for each media center shall include funds for replacing and updating materials.

Each media center shall be supervised by a qualified media specialist who works with students, teachers, and administrators. A full range of information sources, associated equipment, and services from the media center staff shall be available to students and the faculty. Each media center shall be accessible to students throughout the school day. The school or school district shall develop and implement a curriculum guide covering all grade levels operated for instruction and reinforcement of information search and media skills integrated with classroom instruction.

The effective date of this subrule is delayed until July 1, 1990. A school or school district unable to meet the requirements stated in this subrule may file a written request with the department of education that the department waive the requirement until July 1, 1991. The request must be filed with the department of education by January 1, 1990, and shall include the following information: description of current school media services program and staff; reason(s) the school or school district is not able to meet the standard as of July 1, 1990; efforts undertaken to meet the standard including but not limited to attempts to employ staff, share staff, get current staff qualified, adopt appropriate school board policies, adequate facility accessibility, schedule to ensure media center is available to students throughout the school day and other efforts; and specific actions proposed by the school or school district for meeting the standard including proposed timelines for compliance. A request for waiver must be signed by the board president and the chief administrator.

The department of education shall grant the waiver if it is able to determine from the information filed that the school or school district has made a good faith effort to meet the standard and that there is a reasonable expectation that the standard will be met by July 1, 1991.

If a waiver is approved, the school or school district shall for the period of the waiver, be in compliance with the requirements of Iowa Code section 256.11, subsection 9, paragraph *"b."*

DIVISION VI
ACTIVITY PROGRAM

281—12.6(256) Activity program. The following standards shall apply to the activity program of accredited schools and school districts.

12.6(1) *General guidelines.* Each board shall sponsor a pupil activity program sufficiently broad and balanced to offer opportunities for all pupils to participate. The program shall be supervised by qualified professional staff and shall be designed to meet the needs and interests and challenge the abilities of all pupils consistent with their individual stages of development; contribute to the physical, mental, athletic, civic, social, moral, and emotional growth of all pupils; offer opportunities for both individual and group activities; be integrated with the instructional program; and provide balance so a limited number of activities will not be perpetuated at the expense of others.

12.6(2) *Supervised intramural sports.* If the board sponsors a voluntary program of supervised intramural sports for pupils in grades seven through twelve, qualified personnel and adequate facilities, equipment, and supplies shall be provided. Middle school grades below grade seven may also participate.

DIVISION VII
STAFF DEVELOPMENT

281—12.7(256) Staff development. The following standards shall apply to staff development for accredited schools and school districts.

12.7(1) *Staff development program.* The board shall have a plan for staff development. The plan shall provide for the professional development needs of the instructional professional staff, the noninstructional professional staff, the support staff, and educational aides. The plan shall include general goals for a three-year period and specific objectives and activities for the current school year.

12.7(2) *Budget for staff development.* The board shall annually budget specified funds to implement the plan required in subrule 12.7(1).

These rules are intended to implement Iowa Code section 256.17.

These rules will become effective from the standpoint of publication in the Iowa Administrative Code, April 27, 1988. Their effective date for compliance by schools and school districts is July 1, 1989, as provided by Iowa Code section 256.17.

[Filed 3/4/88, Notice 7/15/87—published 3/23/88, effective 4/27/88*]
[Filed 8/19/88, Notice 6/29/88—published 9/7/88, effective 10/12/88]
[Filed emergency 7/7/89—published 7/26/89, effective 7/7/89]
[Filed 10/13/89, Notice 7/26/89—published 11/1/89, effective 12/6/89]

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*Effective date of chapter 4 delayed seventy days by Administrative Rules Review Committee at its April 22, 1988 meeting.

Appendix B

MSC Sample Activities

SAMPLE MSC ACTIVITIES

Multidisciplinary Theme: "Inventions"

Discipline Areas: Science, Math, Social Studies, Writing, Reading, Music, Art, Industrial Technology.

SUGGESTED ACTIVITIES:

* Science - Have students build a crystal radio, and circuits which light bulbs. Discuss electronics, tracking animals with radio devices, and how electricity is made.

* Social Studies - Arrange a trip (or film) to a factory observing the manufacturing of an automobile. Discuss the social significance of the automobile. Have students research inventors who were women or of a minority race and the impact of their inventions.

* Math - Suggest lightweight materials for students to use in the design and building of kites and airplanes. Have the students discuss the kite or airplane they made in terms of shapes, weight, length.

* Writing - Ask the students to write about an invention or machine to do some kind of work they dislike.

* Art - Have students dissect such mechanical objects as clocks, or a small appliance and draw each of the component parts. Then repair them.

* Reading - Ask students to research magic tricks and perform them in class.

* Music - Have students bring to class a few musical instruments to demonstrate. Discuss different sounds, pitches, and tones, and the materials from which they were first invented.

Multidisciplinary Theme: "Living Things"

Discipline Areas: Science, Art, Spelling, Writing, Math

SUGGESTED ACTIVITIES

* Sciences - Arrange a field trip (or pictures) to a grocery store so that students can shop for the ingredients for vegetable soup, and return to the classroom and cook it. Discuss where and how these vegetables were grown, and what happens to them when cooking.

* Art - Provide adhesive, styrofoam, and paint for students to create different types of fruit for display on an exhibit table.

* Spelling - Have students learn to identify and spell the parts of a flower. Have student teams write each flower part-in scrambled word order-on a card. Have teams exchange cards to figure out the correct word and spelling. Have a team competition.

* Writing - Help students create a tree with paper-mache or construction paper with three dimensional leaves, nuts, fruit, and animals about which they place written poems, stories, or factual paragraphs.

* Math - Select easy-to-grow seeds so that students can plant them and measure their growth in metric units from seeds to sprouts to plants.

Multidisciplinary Theme: "Space"

Discipline Areas: Arts, Sciences, Math, Reading, Writing, Social Studies, Music.

SUGGESTED ACTIVITIES

* Sciences - Invite a meteorologist to class to discuss forecasting and the effects of extreme temperatures on soil, growth, and water quality.

* Social Studies - Plan a field trip to an aerospace industry such as a museum, manufacturing plant, or airport. Discuss the social makeup of the employees and why there may not be a lot of women and minorities in the aerospace industry.

* Writing - Have students write about an experience they have had on a ride (at a amusement park) that provided some sensations of space travel.

* Reading - Ask the school librarian to discuss some books on space.

* Art - Have students research the design on space ships through the ages.

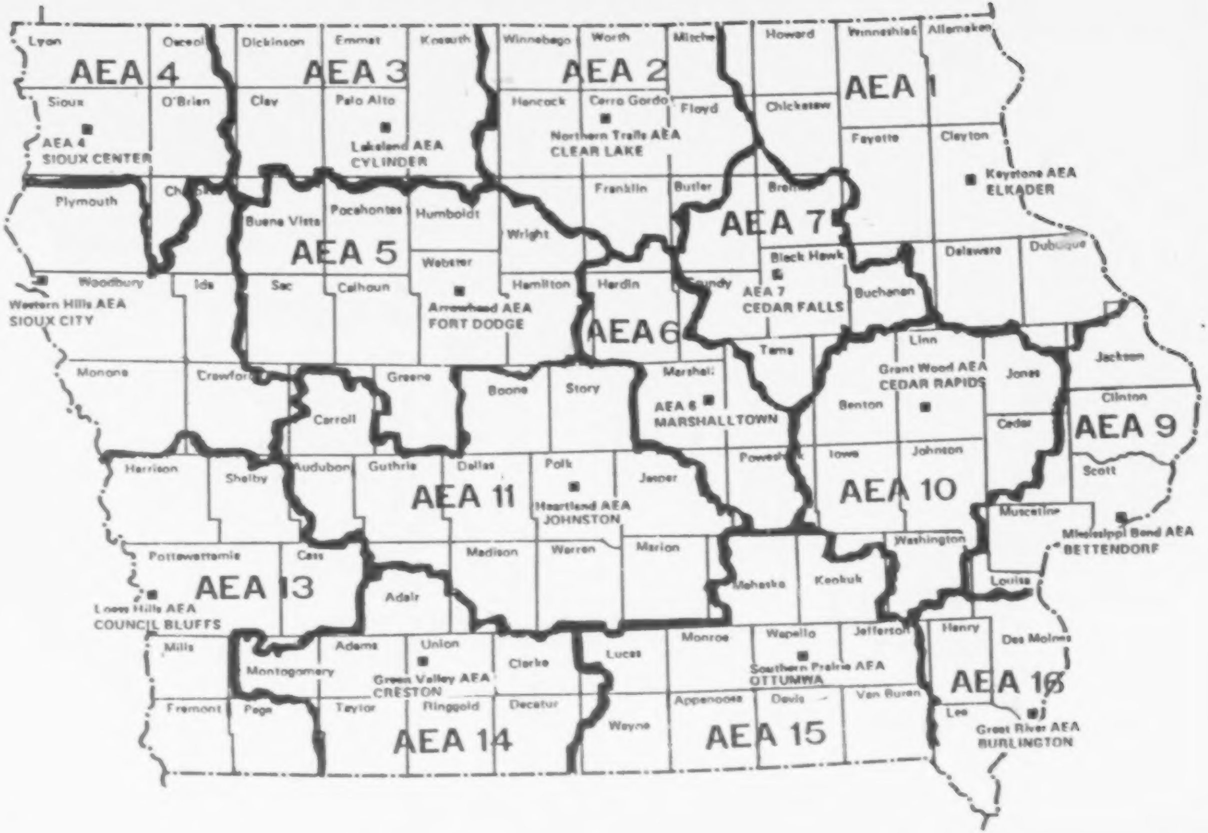
* Math - Ask students to bring space models they may have at home and distinguish between the in by shape, sizes, costs, and distances they can travel.

* Music - Have a team contest naming any songs they know that is named or has lyrics about space, or space travel. Discuss the period time in which these songs were produced.

Appendix C

Area Education Agencies

Area Education Agencies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AEA 7
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AEA 6
AEA 11
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AEA 9
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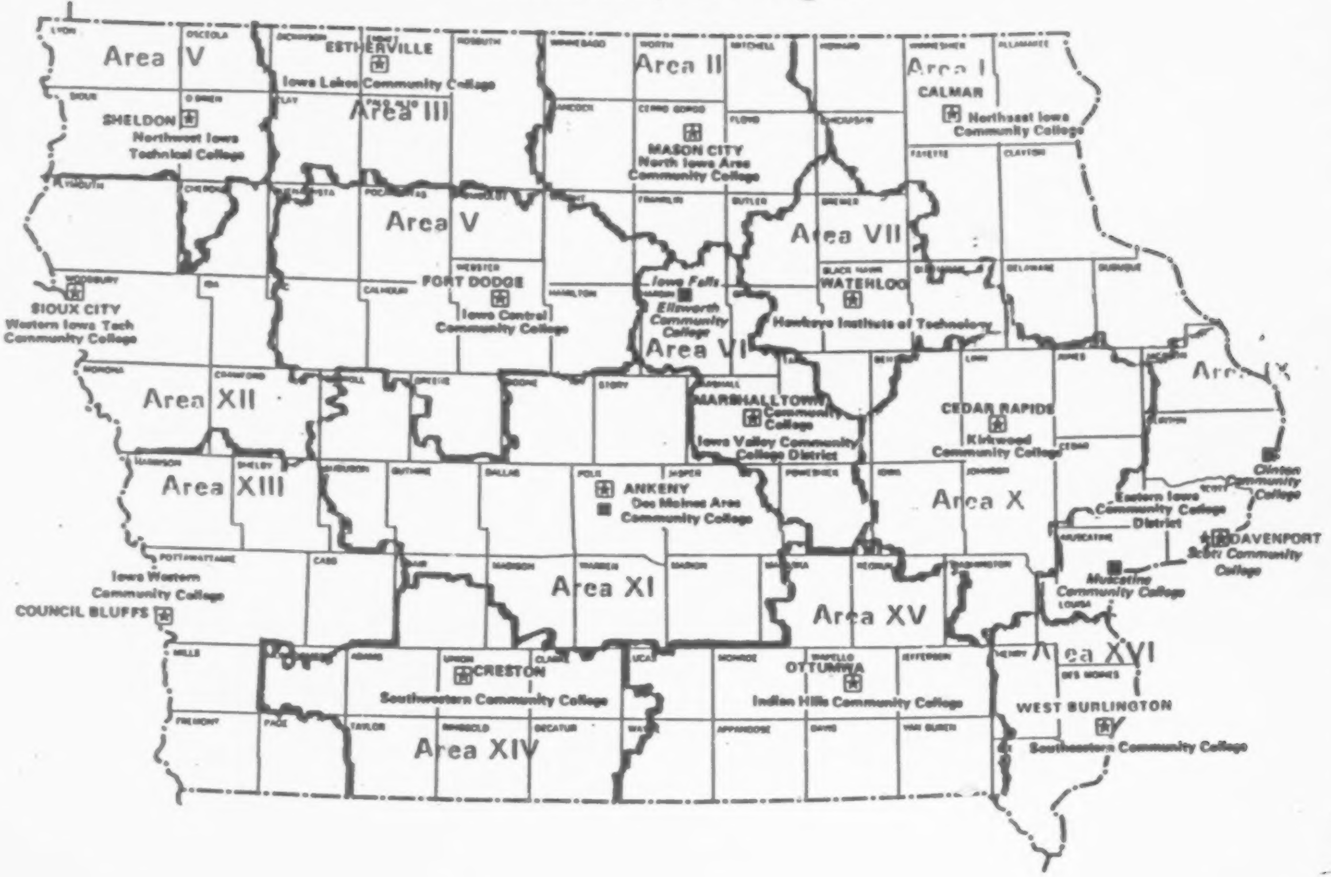
AEA 14
AEA 15
AEA 16
Lyon
Osceol
Dickinson
Emmet
Kossuth
Winnebago
Worth
Mitche
Howard
Winneshiek
Allamakee
Sioux
O'Brien
Clay
Palo Alto
Hancock
Cerro Gordo
Floyd
Chickasaw
Fayette
Clayton
AEA 4
SIOUX CENTER
Lakeland AEA
CYLINDER
Northern Trails AEA
CLEAR LAKE
Keystone AEA
ELKADER
Plymouth
Ch
Buena Vista
Pocahontas
Humboldt
Wright
Franklin
Butler
Bre
Delaware
Dubuque
Woodbury
Ida
Sac
Calhoun
Webster
Hamilton
Hardin
rundy
Black Hawk
Buchanan
Western Hills AEA
SIOUX CITY
Arrowhead AEA
FORT DODGE
AEA 7
CEDAR FALLS
Monona
Crawfor
Carroll
Greene
Boone
Story
Marshall
Tama
Linn
Jones
Jackson
Clinton
AEA 6
MARSHALLTOWN
Grant Wood AEA
CEDAR RAPIDS
Benton
Cedar
Harrison
Shelby
Audubon
Guthrie
Dallas
Polk
Jasper
Powesh
Iowa
Johnson
Scott
Heartland AEA
JOHNSTON
Muscatine
Pottawattamie
Cass
Madison
Warren
Marion
Mahaska
Keokuk
Washington
Louisa
Mississippi Bend AEA
BETTENDORF
Loess Hills AEA
COUNCIL BLUFFS
Adair
Mills
Montgomery
Adams
Union
Clarke
Lucas
Monroe
Wapello
Jefferson
Henry
Des Moines
Green Valley AEA
CRESTON
Southern Prairie AEA
OTTUMWA
Fremont
Page
Taylor
Ringgold
Decatur
Wayne
Appanoose
Davis
Van Buren
Lee
Great River AEA
BURLINGTON

Appendix D

Map of Community Colleges and Telecommunication Down-Link Sites

Community Colleges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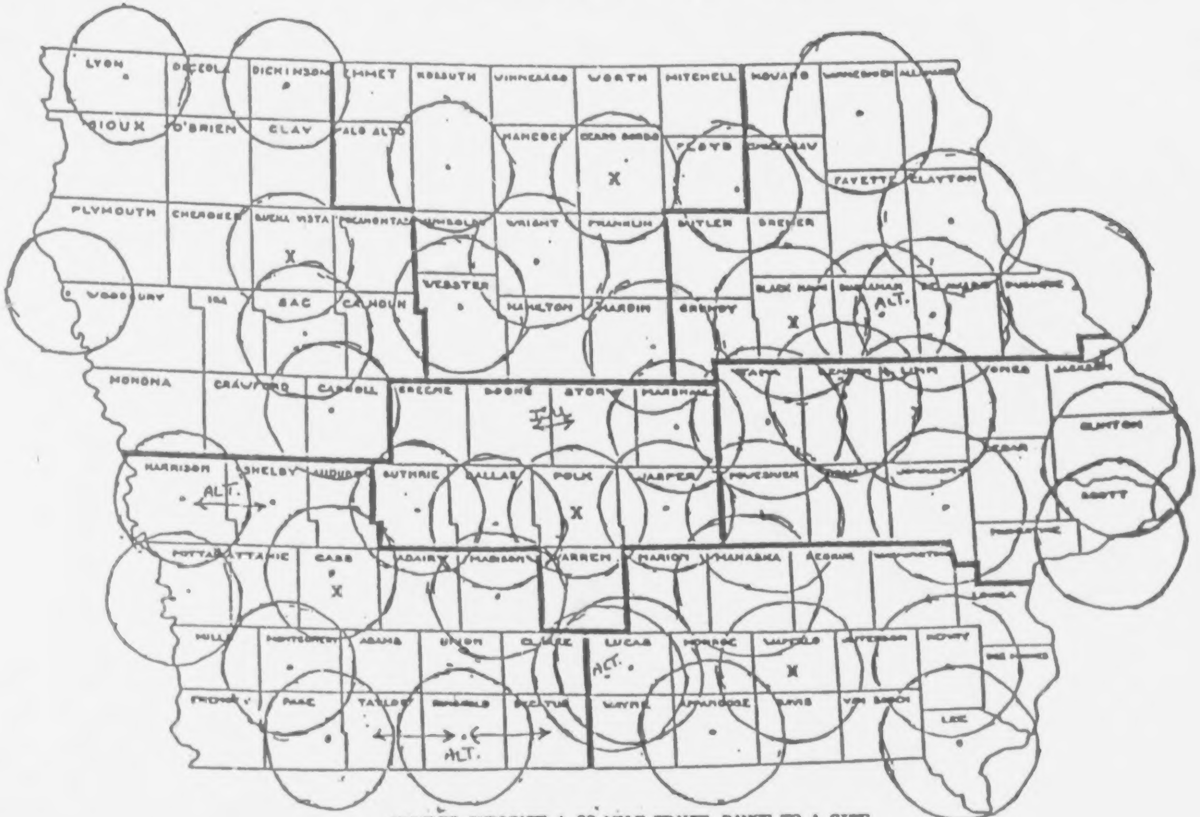
Northwest Iowa Technical College
ESTHERVILLE
Iowa Lakes Community College
Area III
Area II
MASON CITY
North Iowa Area Community College
Area I
CALMAR
Northeast Iowa Community College
Area V
FORT DODGE
Iowa Central Community College
Iowa Falls
Ellsworth Community College
Area VI
Area VII
WATERLOO
Hawkeye Institute of Technology
SIOUX CITY
Western Iowa Tech Community College
Area XII
MARSHALLTOWN
Community College
Iowa Valley Community College District
CEDAR RAPIDS
Kirkwood Community College
Area IX
Clinton Community College
Area XIII
ANKENY
Des Moines Area Community College
Area X
Eastern Iowa Community College District
DAVENPORT
Scott Community College
Muscatine Community College
Iowa Western Community College
COUNCIL BLUFFS
Area XI
Area XV
Area XVI
CRESTON
Southwestern Community College
OTTUMWA
Indian Hills Community College
WEST BURLINGTON
Southeastern Community College
Area XIV

TELECOMMUNICATIONS SATELLITE DOWN-LINK SITES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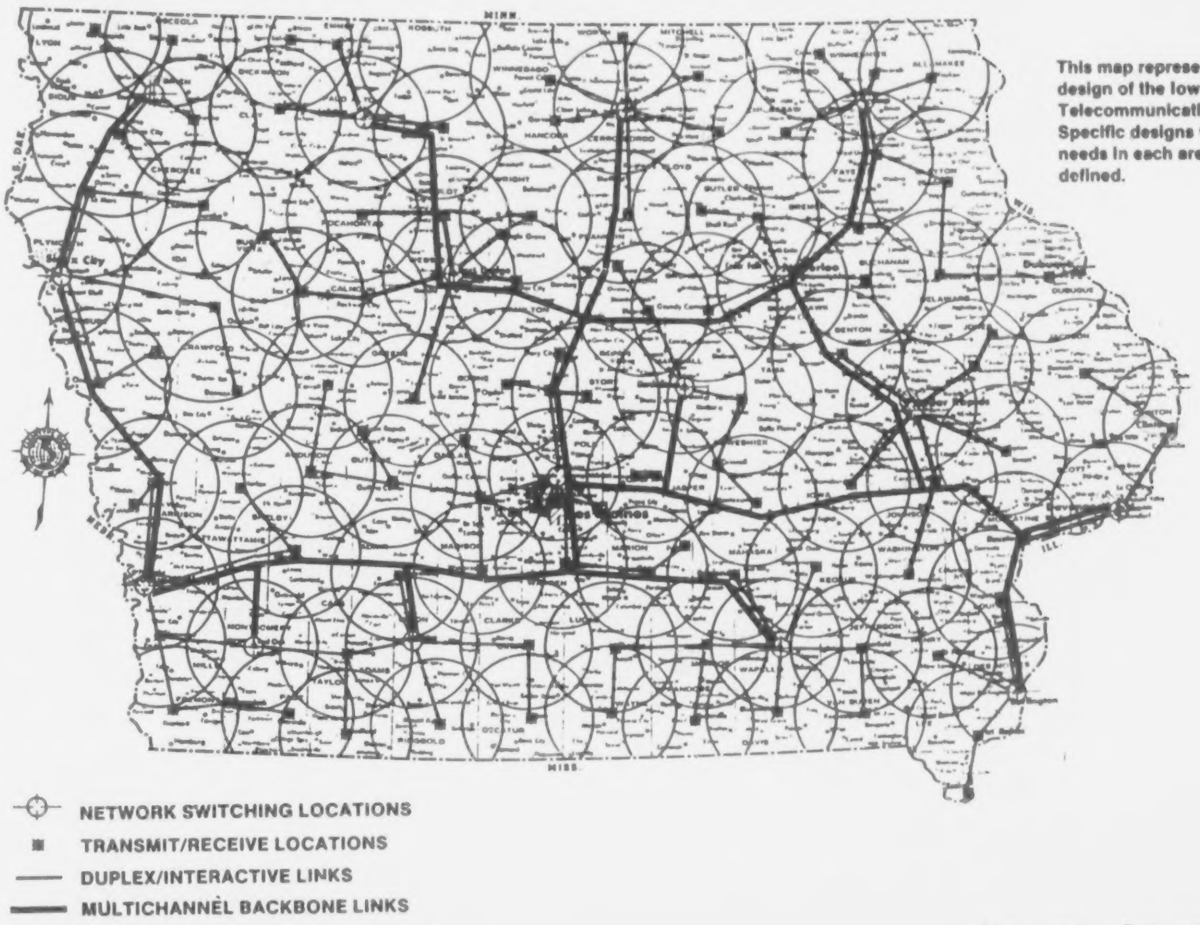
OSCEOLA
DICKINSON
EMMET
KOSSUTH
WINNEBAGO
WORTH
MITCHELL
HOWARD
SIOUX
O'BRIEN
CLAY
PALO ALTO
HANCOCK
CERRO GORDO
FLOYD
FAYETTE
CLAYTON
PLYMOUTH
CHEROKEE
BUENA VISTA
POCAHONTAS
WRIGHT
FRANKLIN
BUTLER
BREMER
WOODBURY
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
BLACK HAWK
BUCHANAN
ALT.
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
MARSHALL
TAMA
LINN
JONES
JACKSON
CLINTON
CEDAR
SCOTT
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
POWESHIEK
ALT.
POTTAWATTAMIE
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
KEOKUK
MILLS
MONTGOMERY
ADAMS
UNION
CLARKE
LUCAS
MONROE
WAPELLO
JEFFERSON
HENRY
ALT.
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE
ALT.
X

CIRCLES INDICATE A 20 MILE TRAVEL RANGE TO A SITE
ALT. INDICATES ALTERNATE SITES ARE UNDER CONSIDERATION

IOWA EDUCATIONAL TELECOMMUNICATIONS NETWORK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S. DAK.
NEBR.
MISS.
WIS.
ILL.
Sioux City
Des Moines
Waterloo
Dubuque
Cedar Rapids
CRAWFORD
HARRISON
POTTAWATTAMIE
MONTGOMERY
TAYLOR
ADAMS
RINGGOLD
DECATUR
CLARKE
LUCAS
WAPELLO
VAN BUREN
JEFFERSON
WASHINGTON
MAHASKA
MARION
JASPER
POWESHIEK
TAMA
BENTON
BUCHANAN
DELAWARE
JACKSON
CLINTON
SCOTT
STORY
CALHOUN
POCAHONTAS
CHEROKEE
DICKINSON
KOSSUTH
WINNEBAGO
HANCOCK
WORTH
MITCHELL
CERRO GORDO
FLOYD
BUTLER
WRIGHT
ALLAMAKEE
WINNESHIEK
HOWARD
LYON
SIOUX
OSCEOLA
PLYMOUTH
NETWORK SWITCHING LOCATIONS
TRANSMIT/RECEIVE LOCATIONS
DUPLEX/INTERACTIVE LINKS
MULTICHANNEL BACKBONE LINKS

This map represents a preliminary design of the Iowa Educational Telecommunications Network. Specific designs will evolve as the needs in each area are further defined.

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Appendix E

Iowa Council of State Science Supervisors

Iowa Council of Teachers of Mathematics

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Albia, Iowa 52531

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Cedar Falls, Iowa 50613

Julie Grotewold (515/682-8591)
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Building 40, Industrial Airport
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Alan Maxwell
Osage Junior High School
Osage, Iowa 50461

Mr. Dave McCalley (319/273-2456)
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University of Northern Iowa
Cedar Falls, Iowa 50613

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Appendix F

The Iowa Assessment Package for Evaluation

Five Domains of Science Education

(Full copy available upon request)

THE IOWA ASSESSMENT PACKAGE
FOR EVALUATION IN
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EVALUATION IN FIVE DOMAINS OF SCIENCE EDUCATION

Teachers have long appreciated that science is a complex discipline which includes many facets or domains. Researchers have identified five principal aspects within science and science teaching including concepts, processes, applications, creativity, and attitudes. These domains exist in terms of common instructional and curricular goals but yet growth in all domains is rarely tested. Analysis indicates that more than 90 percent of typical test items on standardized instruments, textbook exams, and teacher-made tests deal solely with the degree of student retention of the meaning of basic concepts included in the curriculum, while other important areas are completely neglected. At least, the other domains are thought to be of less importance, too difficult to measure, or dependent upon students first knowing basic concepts. This package has been developed to suggest ways in which a wider assessment scheme may be initiated.

There are many effective curriculum and instructional models for the exploration of domains other than information acquisition; this package has been designed to show how those areas may be evaluated. Use of the methods for assessment provided would constitute a more complete evaluation program than is usually practiced. Teachers are encouraged to explore the other ideas which are available in each domain and develop personal models for assessment. We are anxious to have such items added to the Iowa Assessment Package as ideas and models for others.

Domain I - Knowing and Understanding (Concepts Domain)

Science aims to categorize the observable universe into manageable units for study and to describe physical and biological relationships. Ultimately, science aims to provide reasonable explanations for observed relationships. Part of any science instruction involves student learning some of the concepts central to science. Certainly student understanding of current explanations of objects and events in the universe is important, particularly when students use what they have learned.

The Knowing and Understanding Domain includes:

- Facts
- Information
- Concepts
- Laws (Principles)
- Existing explanations and theories being used by scientists
- Internalized knowledge which can be used

All of this vast amount of information is usually classified into such manageable topics such as matter, energy, motion, animal behavior, plant development. Often teachers, curriculum developers, and textbook publishers assume that the beginning point for curriculum and instruction is an understanding of such basic concepts.

Domain II - Exploring and Discovering (Process Domain)

How scientists think and work represents another dimension of science. There are specific and definable processes that characterize human actions that result in new knowledge of the universe. Generally these processes are embodied in the terms "exploring and discovering." Processes of science identified by AAAS in the development of *Science: A Process Approach* represent a generally accepted set of processes scientists use. They can be targets for instruction themselves. The 13 processes identified by AAAS include:

- Observing
- Using Space/Time Relationships
- Classifying, grouping and organizing
- Using Numbers, quantifying

- Measuring
- Communicating
- Inferring
- Predicting
- Controlling and Identifying variables
- Interpreting Data
- Formulating Hypotheses
- Defining Operationally
- Experimenting

Certainly it is the hope that these processes can have applicability for all learners. To know the processes means being able to use them in a wide variety of situations. Demonstrating such use is often the failure for school science.

Domain III - Using and Applying (Applications Domain)

It seems pointless to have any science program if the program does not include some substantial amount of information, skills, and attitudes that can be transferred and used in students' everyday lives. Also, it seems inappropriate to divorce "pure" or "academic" science from technology. Students need to become sensitized to those experiences they encounter which reflect ideas they have learned in school science. Some dimensions of this domain are:

- Seeing instances of scientific concepts in everyday life experiences
- Applying learned science concepts and skills to everyday technological problems
- Understanding scientific and technological principles involved in household technological devices
- Using scientific processes in solving problems that occur in everyday life
- Understanding and evaluating mass media reports of scientific developments
- Making decisions related to personal health, nutrition, and life style based on knowledge of scientific concepts rather than on "hear-say" or emotions
- Integrating science with other subjects
- Taking specific actions designed to resolve problems and/or to improve a local, regional, national, and/or international problem
- Becoming involved in community-action projects; extending school experiences beyond the classroom
- Emphasizing the interrelationships and interconnectedness of science to other human enterprises

To be meaningful the material in science courses should be related to real life situations. For many this means first focusing on technology which are applications of science. Such applications provide connections and a means of enhancing creativity and attitude. When these are enhanced, more persons can see the value of processes and concepts; perhaps more will advance to these more commonly emphasized domains because they see relevance rather than accepting the teacher assertion that it will be useful in the future.

Domain IV - Imagining and Creating (Creativity Domain)

Most science programs view science as something to be done to students to help them learn a given body of information. Little formal attention has been given in science programs to the development of students' imagination and creative thinking. Scientists themselves apply creative solutions to real problems frequently. Therefore, it is reasonable for science educators to encourage the development and expansion of students' creative abilities. Here are some of the human abilities important in this domain:

- Visualizing - producing mental images
- Combining objects and ideas in new ways

- Producing alternate or unusual uses for objects
- Solving problems and puzzles
- Fantasizing
- Pretending
- Dreaming
- Designing devices and machines
- Producing unusual ideas
- Identifying
- Isolating
- Merging
- Diverging
- Converging

Much research and development has been done relative to the development of students' abilities in this domain, but little has been incorporated into science programs. Some of Torrance's work has focused upon questioning, identifying possible causes for a situation or event, and predicting consequences for a given happening. Creativity is involved with the quantity in each category as well as the quality and the uniqueness of the question, possible causes, or predicted consequences. Concern for student growth in these creativity areas is vital for teachers knowledgeable about the basic ingenuities of science itself.

Domain V - Feeling and Valuing (Attitudes Domain)

In these times of increasingly complex social and political institutions, environmental and energy problems, and general worry about the future, scientific content, processes, and even attention to imagination are not sufficient parameters for a science program. Human feelings, values, and decision-making skills need to be addressed. Science programs should exert positive influence on the development of more positive attitudes towards science, science courses, and science learning. This domain includes:

- Developing positive attitudes toward science in general, science in school, and science teachers
- Developing positive attitudes toward oneself (an "I can do it" attitude)
- Exploring human emotions
- Developing sensitivity to, and respect for, the feelings of other people
- Expressing personal feelings in a constructive way
- Making decisions about personal values
- Making decisions about social environmental issues
- Exploring arguments on either side of an issue

All learning is enhanced when students have a positive attitude. They are more motivated, more involved with meeting the course objectives, more likely to realize instructional goals. Negative attitudes discourage many and tend to make program goals trivial, even for those who wish generally to excel in school.

THE IOWA ASSESSMENT PACKAGE

In the following section of the Booklet, instruments for assessing students' growth in each of the five domains of science teaching is provided. Directions are given on how to use the instrument. Student response sheets and teacher's tabulation sheets are provided when appropriate. No standard tests will be provided for the Concepts and Applications domains because the content of these tests will vary tremendously from teacher to teacher depending on the tested module. Guidelines for constructing assessment tests will be provided particularly for the Concepts and Applications domains. The table following lists the reliabilities for the instruments in the Process, Creativity, and Attitude domains.

Guidelines and instruments for assessing students' growth in each of the five domains of science teaching are provided in this package. Directions are given on how to use the instruments included in this package. Student response sheets and class tabulation sheets are provided when appropriate. No standard tests will be provided for the concept and application domains because it is the teacher who will decide on these test items and relate them directly to the content being taught in a specific module. Guidelines for constructing assessment items and instruments are provided for the concept and application domains. The table below provides reliability information for the process, creativity, and attitude instruments included in this package. The reliability coefficient was obtained by using the Test-retest method with students in classes taught by lead teachers. Parallel forms were used for each of the domains. The scores were correlated using the MINITAB statistical package.

Instruments' Reliability

DOMAIN	INSTRUMENT	RELIABILITY	POPULATION NUMBER & GRADE LEVEL		SOURCE
Processes	Processes of Science	0.72	846	4-5	Wallace (1974)
		0.80	490	4-9	Yager (1990)
Creativity	Creative Thinking Assessment Model	0.77	57	6-7	Yager (1990)
Attitude	Preferences and Understanding	0.82	456	K-6	Kyle, Bonnstetter, & Gadsden (1988)
		0.83	456	4-9	Yager (1990)

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John Lewis
Iowa Alliance for Science
Iowa Utility Association

Myrna Whigham
Iowa Assoc. of Women in Science and
Engineering

John Cook
Area Education Agency 6

Linda Schatz
Iowa Public Television

Becky Butler
IBM

Robert Houser
Iowa Business Education Roundtable

Tom Glenn
South Central Iowa AFL-CIO

Advisory Board Continued

Kirk Brocker
Science Center of Iowa

Liz Goodwin
Iowa Parent Teacher Association

John Hartung
Iowa Association of Independent Colleges and Universities

K. J. Clark
Iowa Parent Teacher Association

Jim Austin, Superintendent
South Tama Community School District

Legislative Advisers

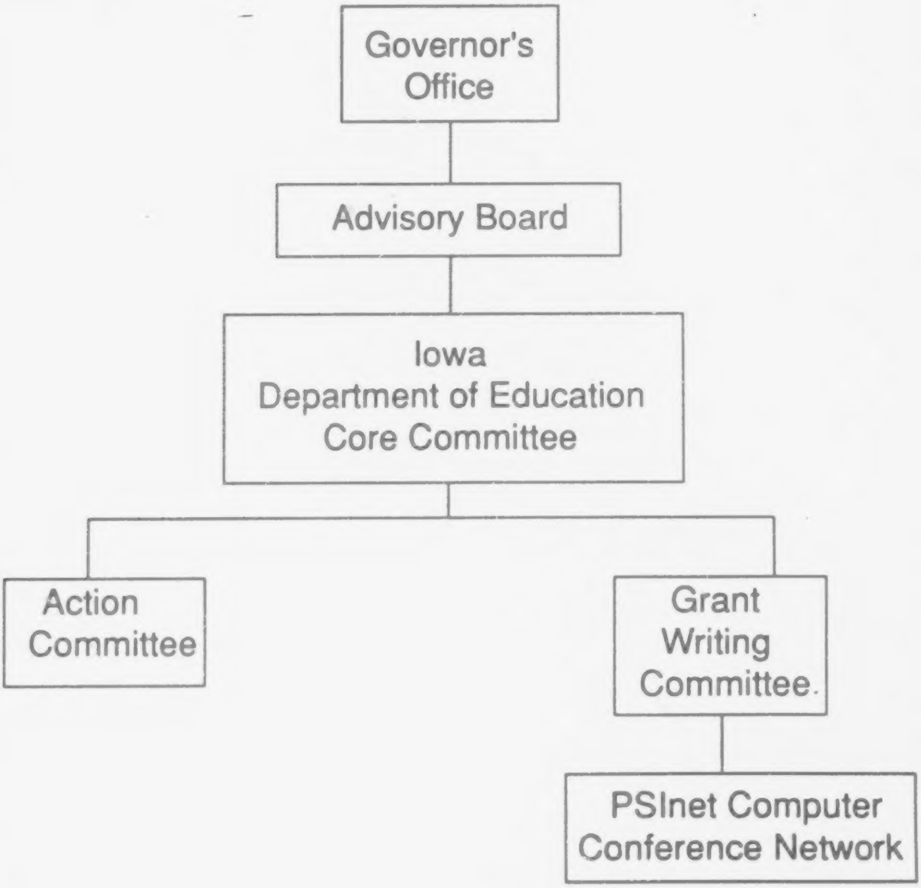
Representative Art Ollie
Representative Horace Daggett
Senator Larry Murphy
Senator Ray Taylor

Representative Jack Hatch
Representative Ruhl Maulsby
Senator Richard Varn
Senator Wilmer Rensink

Appendix H

Iowa's Planning Process

IOWA'S PLANNING PROCESS FOR NSF'S SOLICITATION IMPROVE MATH AND SCIENCE EDUCATION


Governor's Office
Advisory Board
Iowa Department of Education Core Committee
Action Committee
Grant Writing Committee
PSInet Computer Conference Network

A listing of members of the various committees is given on the following page.

APPENDIX VII

MARKUP OF FISCAL YEAR 1992 AND 1993 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

THURSDAY, MAY 2, 1991

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:10 a.m. in room 2318, Rayburn House Office Building, Hon. Rick Boucher [chairman of the subcommittee] presiding.

Mr. BOUCHER. The subcommittee will come to order.

The Chair calls up the draft bill entitled the National Science Foundation Authorization Act Amendments of 1991.

The Chair recognizes itself for a statement explaining the draft legislation.

The purpose of the bill is to authorize appropriations for the National Science Foundation's scientific directorates for fiscal years 1992 and 1993. The current NSF authorization law, which extends through fiscal year 1993, includes an authorization for Research and Related Activities for those two fiscal years, but not for the individual directorates within the Research and Related Activities category. The current law authorizes approximately $500 million more than the President's request for fiscal year 1992. The draft bill lowers the fiscal year 1992 NSF authorization to $2.72 billion, which is the level of the President's request, and that is 17.5 percent above the fiscal year 1991 appropriation level.

Relative to the President's request, the only changes in the draft bill for specific funding categories are to reduce the Mathematical and Physical Sciences request by $23.5 million; to increase the Academic Research Facilities Modernization Program request from zero to $40 million; and to decrease the Academic Research Instrumentation Program request from $50 million to $33.5 million.

Authorization hearings previously held by this subcommittee this year highlighted the necessity for adequate research laboratory space in order to support modern research instrumentation. The draft bill therefore authorizes the new Instrumentation Program while sustaining the Facilities Program, which has been funded at $20 million per year for each of the past two years. The $23.5 million shifted from Mathematical and Physical Sciences to the Facilities Program is accompanied by a prohibition on construction of the Laser Interferometer Gravitational Wave Observatory, otherwise known as LIGO, in fiscal year 1992. That prohibition is for that fiscal year only.

The prohibition on construction of LIGO does not extend to laboratory research or to design studies related to perfecting the LIGO project. The intention of the provision is to require NSF to reconsider the timeliness of proceeding with full-scale development of LIGO in light of the recent National Academy of Sciences' astronomy survey report. The Academy's report did not endorse LIGO. It placed instead, high priority on the repair and maintenance of existing astronomy facilities.

Questions regarding the adequacy of the projected measurement sensitivity of LIGO were raised before this subcommittee, and it is our view that those questions should be addressed by the National Science Board before proceeding to full development of the LIGO project. In that regard, next year the subcommittee will welcome information from the National Science Board that addresses those matters.

For fiscal year 1993, the draft bill lowers the NSF authorization now in the statute to $3.07 billion, the level of NSF's three-year budget projection which was submitted to the Congress with the President's fiscal year 1992 budget request. That funding level provides an increase of 14 percent for Research and Related Activities and an increase of 12.7 percent for Education and Human Resources, both above the fiscal year 1992 authorization levels contained in the draft bill. Increases of 10 percent and 7.4 percent are provided for the Facilities and Instrumentation Programs, respectively.

The draft bill endorses the most recent plan of the Administration to complete doubling of the NSF budget by fiscal year 1994. It strengthens the research programs, which have seen very little real growth over the last few years. It sustains growth of education activities, and it provides for modest but highly leveraged research facilities modernization and research instrumentation programs.

It is the Chair's pleasure to commend the draft for consideration of the subcommittee.

[The prepared statement of Mr. Boucher follows:]

OPENING STATEMENT OF THE HONORABLE RICK BOUCHER (D-VA) CHAIRMAN, SUBCOMMITTEE ON SCIENCE ON MARKUP OF THE NATIONAL SCIENCE FOUNDATION AUTHORIZATION ACT AMENDMENTS OF 1991

MAY 2, 1991

The chair calls up the draft bill entitled the National Science Foundation Authorization Act Amendments of 1991.

The purpose of the bill is to authorize appropriations for the NSF scientific directorates for FY 1992 and FY 1993. The current NSF authorization law, which extends through FY 1993, includes an authorization for Research and Related Activities for FY 1992 and FY 1993, but not for the individual directorates within Research and Related Activities. The current law authorizes approximately $500 million more than the President's request for FY 1992 because the five-year authorization law allowed for doubling the NSF budget by FY 1992, and also established the Academic Research Facilities Modernization program funded at $250 million per year.

The draft bill lowers the FY 1992 NSF authorization to $2.72 billion, the level of the President's request, which is 17.5 percent above the FY 1991 appropriation level. Relative to the President's request, the only changes in the draft bill for specific funding categories are to reduce the Mathematical and Physical Sciences request by $23.5 million, to increase the Academic Research Facilities Modernization program request from zero to $40 million, and to decrease the Academic Research Instrumentation program from $50 million to $33.5 million.

Authorization hearings before the Subcommittee in March highlighted the necessity for adequate research laboratory space in order to support modern research instrumentation. The draft bill, therefore, authorizes the new instrumentation program while sustaining the facilities program, which has been funded at $20 million per year for the past two years. The $23.5 million shifted from Mathematical and Physical Sciences to the facilities program is accompanied by a prohibition on construction of the Laser Interferometer

Gravitational Wave Observatory, called LIGO, in FY 1992.

The prohibition on construction of LIGO does not extend to laboratory research or to design studies related to LIGO. The intention of the provision is to require NSF to reconsider the timeliness of proceeding with full scale development of LIGO in light of the recent National Academy of Sciences astronomy survey report. The Academy's report did not endorse LIGO. It placed instead high priority on the repair and maintenance of existing astronomy facilities. Questions regarding the adequacy of the projected measurement sensitivity of LIGO were also raised at the Subcommittee's March 13th NSF authorization hearing. The Subcommittee will welcome next year information from the National Science Board addressing these issues.

For FY 1993, the draft bill lowers the NSF authorization now in the statute to $3.07 billion, the level of NSF's three-year budget projection which was submitted to Congress with the President's FY 1992 budget request. This *funding level provides an increase of 14 percent for Research and Related Activities and an increase of 12.7 percent for Education and Human Resources above the FY 1992 authorization levels in the draft bill. Increases of 10 percent and 7.4 percent are provided for the facilities and instrumentation programs, respectively.*

The draft bill endorses the most recent plan of the Administration to complete doubling of the NSF budget by FY 1994; strengthens the research programs, which have seen little real growth over the past few years; sustains growth of education activities; and provides for modest, but highly leveraged, research facilities modernization and research instrumentation programs. I am pleased to commend this draft bill to the Subcommittee for its consideration.

Mr. **Boucher**. That completes the Chair's opening statement, and the Chair is now pleased to recognize the ranking Republican member of this subcommittee, the gentleman from California, Mr. Packard.

Mr. **Packard**. Thank you, Mr. Chairman.

I would like to thank you for scheduling the markup of this authorization bill, the National Science Foundation budget for fiscal years 1992 and 1993. I am very glad to see the numbers in the President's request, which evidence an intent to follow through with the plan to double the National Science Foundation's budget by 1994.

The bill before us today provides funding for many exciting programs and initiatives, such as research in the Antarctic, research into global change, funding for the Interagency High Performance Computing Initiative, and funding for materials synthesis and processing.

An area of vital importance to the future of this Nation is the money that is being spent on education and the money that is being spent on research. Basic research is fundamental to this Nation's continued international competitiveness, and education is essential for the training of those individuals who will eventually carry on that research.

Mr. Chairman, I wish to conclude by saying that I generally support the bill that is before us today, the only exception being the total funding amount in 1993, which I will address with an amendment.

I want to thank you very much for scheduling the hearing.

[The prepared statement of Mr. Packard follows:]

STATEMENT OF
THE HONORABLE RON PACKARD (R-CA)
SCIENCE SUBCOMMITTEE MARKUP
NATIONAL SCIENCE FOUNDATION AUTHORIZATION ACT AMENDMENTS OF 1991

10:00 A.M., 2318 RHOB
MAY 2, 1991

I WOULD LIKE TO THANK THE CHAIRMAN FOR SCHEDULING THIS MARKUP FOR THE AUTHORIZATION OF THE NATIONAL SCIENCE FOUNDATION FOR FISCAL YEARS 1992 AND 1993. I AM GLAD TO SEE THE NUMBERS IN THE PRESIDENT'S REQUEST WHICH EVIDENCE AN INTENT TO FOLLOW THRU WITH THE PLAN TO DOUBLE THE NATIONAL SCIENCE FOUNDATION'S BUDGET BY 1994.

THE BILL BEFORE US TODAY PROVIDES FUNDING FOR MANY EXCITING PROGRAMS AND INITIATIVES, SUCH AS: RESEARCH IN THE ANTARCTIC; RESEARCH INTO GLOBAL CHANGE; FUNDING FOR THE INTERAGENCY HIGH PERFORMANCE COMPUTING INITIATIVE; AND FUNDING FOR MATERIALS SYNTHESIS AND PROCESSING.

AN AREA OF VITAL IMPORTANCE TO THE FUTURE OF

THIS NATION IS THE MONEY THAT IS BEING SPENT ON EDUCATION AND THE MONEY THAT IS BEING SPENT ON RESEARCH. BASIC RESEARCH IS FUNDAMENTAL TO THIS NATION'S CONTINUED INTERNATIONAL COMPETITIVENESS AND EDUCATION IS ESSENTIAL FOR THE TRAINING OF THOSE INDIVIDUALS WHO WILL EVENTUALLY CARRY ON THAT RESEARCH.

MR. CHAIRMAN, I WILL CONCLUDE BY SAYING THAT I GENERALLY SUPPORT THE BILL THAT IS BEFORE US TODAY. THE ONLY EXCEPTION BEING THE TOTAL FUNDING AMOUNT FOR FY93. I WILL ADDRESS THESE CONCERNS WHEN I OFFER MY AMENDMENT. THANK YOU MR. CHAIRMAN.

Mr. **Boucher**. The Chair thanks the gentleman for his remarks and inquires if there are other members of the subcommittee who seek recognition for an opening statement.

The gentleman from New Mexico?

Mr. **Schiff**. Thank you, Mr. Chairman. I have no formal opening statement. I just want to say that the National Science Foundation is very important to us and the scientific community, and I appreciate your holding this hearing.

Mr. **Boucher**. The Chair thanks the gentleman.

The Chair asks unanimous consent that the subcommittee print be considered as the subcommittee markup vehicle and original text for the purpose of markup.

[No response.]

Mr. **Boucher**. Hearing no objection, it is so ordered.

[The subcommittee print follows:]

BOUCHE070

HLC

102D CONGRESS
1ST SESSION

H. R. ___

IN THE HOUSE OF REPRESENTATIVES

Mr. BOUCHER introduced the following bill; which was referred to the Committee on _____________

A BILL

To amend the National Science Foundation Authorization Act of 1988, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the ``National Science Foundation Authorization Act Amendments of 1991''.

SEC. 2. AUTHORIZATION OF APPROPRIATIONS.

(a) FISCAL YEAR 1992.--Section 101(e) of the National Science Foundation Authorization Act of 1988 is amended to read as follows:

``(e) There are authorized to be appropriated to the Foundation $2,722,000,000 for fiscal year 1992, which shall be available for the following categories:

``(1) Research and Related Activities, $1,940,000,000, which shall be available for the following subcategories:

``(A) Mathematical and Physical Sciences, $626,580,000.

``(B) Engineering, $247,700,000.

``(C) Biological, Behavioral, and Social Sciences, $355,640,000.

``(D) Geosciences, $419,540,000.

``(E) Computer and Information Science and Engineering, $229,500,000.

``(F) Scientific, Technological, and International Affairs, $61,040,000.

``(2) Education and Human Resources, $390,000,000.

``(3) United States Antarctic Program, $193,000,000.

``(4) Academic Research Facilities Modernization Program, $40,000,000.

``(5) Academic Research Instrumentation Program, $33,500,000.

``(6) Salaries and Expenses, $122,000,000.

``(7) Office of Inspector General, $3,500,000.''.

(b) FISCAL YEAR 1993.--Section 101(f) of the National Science Foundation Authorization Act of 1988 is amended to read as follows:

``(f) There are authorized to be appropriated to the Foundation $3,070,000,000 for fiscal year 1993, which shall be available for the following categories:

``(1) Research and Related Activities, $2,210,000,000, which shall be available for the following subcategories:

``(A) Mathematical and Physical Sciences, $731,460,000.

``(B) Engineering, $278,325,000.

``(C) Biological, Behavioral, and Social Sciences, $400,400,000.

``(D) Geosciences, $472,665,000.

``(E) Computer and Information Science and Engineering, $258,790,000.

``(F) Scientific, Technological, and

International Affairs, $68,360,000.

``(2) Education and Human Resources, $440,000,000.

``(3) United States Antarctic Program, $210,000,000.

``(4) Academic Research Facilities Modernization Program, $44,000,000.

``(5) Academic Research Instrumentation Program, $36,000,000.

``(6) Salaries and Expenses, $126,000,000.

``(7) Office of Inspector General, $4,000,000.''.

(c) LIMITATION.--Section 101 of the National Science Foundation Authorization Act of 1988 is amended by adding at the end the following new subsection:

``(i) Of the amount authorized in subsection (e), no funds shall be available for construction of the Laser Interferometer Gravitational Wave Observatory. This limitation shall not apply to expenditure of funds for research activities or design studies associated with such project.''.

SEC. 3. ADMINISTRATIVE AMENDMENTS.

Section 5(e) of the National Science Foundation Act of 1950 (42 U.S.C. 1864) is amended by striking the last sentence of paragraph (2).

Mr. BOUCHER. Without objection, the text will be considered as having been read and will be open for amendment at any point.

The Chair recognizes the gentleman from California.

Mr. PACKARD. Thank you, Mr. Chairman. I have an amendment that I categorize as a technical amendment, simply to correct some figures. On page 3, line 12, we change the figure from $3.07 billion and insert in lieu thereof $3.068 billion, a change of $2 million.

On page 4, line 2, a change of $1 million.

On page 4, line 5, a change of $1 million.

We are representing that this bill is in conformance to the President's estimates, and these technical corrections will bring it literally into conformance, and that's my intent. It's certainly not to change the fundamental commitment to these programs. I think it still leaves them very much intact. That is the fundamental part of my amendment.

[The amendment offered by Mr. Packard follows:]

page 3, line 12, strike "3,070,000,000" and insert in lieu thereof "3,068,000,000".
page 4, line 2, strike "440,000,000" and insert in lieu thereof "439,000,000".
page 4, line 5, strike "44,000,000" and insert in lieu thereof "43,000,000".

Mr. BOUCHER. The Chair thanks the gentleman for offering his amendment and states its support for the gentleman's proposal, and asks if there is other discussion concerning the amendment of the gentleman from California.

[No response.]

Mr. BOUCHER. If not, the question occurs on the amendment. Those in favor will say aye.

[Chorus of ayes.]

Mr. BOUCHER. Those opposed, no.

[No response.]

Mr. BOUCHER. The ayes have it. The amendment is agreed to.

Are there further amendments to the markup vehicle?

[No response.]

Mr. BOUCHER. The Chair sees no hands seeking recognition. Therefore, the gentleman from California is recognized for the purposes of a motion.

Mr. PACKARD. Mr. Chairman, I move that the subcommittee report the bill as amended. Furthermore, I move to instruct the staff to prepare the subcommittee report, to make any necessary technical and conforming amendments, and that the chairman take all necessary steps to bring the bill before the full committee for consideration.

Mr. BOUCHER. The question is on the motion of the gentleman from California. Those in favor will say aye.

[Chorus of ayes.]

Mr. BOUCHER. Those opposed, say no.

[No response.]

Mr. BOUCHER. The ayes have it and the bill is reported in accordance with the instructions contained in the motion.

The legislation will be introduced next Tuesday, May 6th, and the Chair invites all members of the subcommittee to become copatrons of the measure and very much hopes that will be the case. The staff will be contacting the offices of members with requests for cosponsorship.

There being no further matters to come before the subcommittee this morning, the markup session is adjourned.

[Whereupon, at 10:18 a.m., the subcommittee adjourned, to reconvene at the call of the Chair.]

MARKUP OF FISCAL YEAR 1992 AND 1993 NATIONAL SCIENCE FOUNDATION AUTHORIZATION

WEDNESDAY, MAY 22, 1991

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The committee met, pursuant to notice, at 10:27 a.m. in room 2318, Rayburn House Office Building, Hon. George E. Brown, Jr., [chairman of the committee] presiding.

Mr. BROWN. The committee will come to order.

Obviously, a lot of important business is still being transacted up here, but we need to move ahead.

This morning, the committee will take up three authorization bills: H.R. 2282, the National Science Foundation Authorization Act Amendments of 1991; H.R. 2399, the Energy Technology Research and Development Authorization Act of 1991; and H.R. 2404, the Environmental Research, Development, and Demonstration Authorization Act of 1991.

After today's markup, the committee will have completed its markups of all the major authorization bills. It's the first time in many years that the committee has ordered reported all of its authorization bills before the Memorial Day recess. I think this is a noteworthy event, and I want to commend all of the subcommittee chairs and the ranking Republican members for their hard work in moving these bills through to the full committee in such a timely and cooperative fashion.

With these bills, we have also exercised budget discipline and met the commitment to set priorities and make hard decisions. Taken together, the funding in all of the committee's authorization bills does not exceed the total funding requested in the President's budget for the agencies under this committee's jurisdiction, and that also sets a record of sorts.

Setting priorities within the President's budget request has not been an easy task. Many of us can identify worthwhile programs which simply will not be funded at levels we believe are appropriate. There simply isn't enough money in the budget to do all that we can to bolster our economic competitiveness in the global high-technology market; to fund cutting-edge scientific research in a wide field of scientific disciplines; to explore space, the final frontier, to find new ways to use energy cleanly and wisely; and to protect and clean up our environment. As in any political process, we have made compromises, and while not everyone is happy about everything in all of our bills, I'm confident that most of the members share my view that we have arrived at an appropriate consensus on our science funding priorities as far, as we can determine at this time.

I want to commend all of the members of the committee on both sides for their efforts in this first-time effort to set some meaningful priorities for the programs under our jurisdiction.

I might add just briefly to that that there remain, of course, a few items which have not been fully resolved or worked out and, in fact, are in the process of being negotiated. We will try and defer including these in today's legislation until we have reached some sort of a consensus on it, and I intend, in that event, to bring these relatively small number of additional items to the floor as Chairman's amendments after we have had further negotiations on them. I make this as a good faith promise, and I hope that this will make some people, at least, a little less unhappy at the thought that they didn't get everything that they may have wanted in the legislation before us.

Now, let me at this point recognize our ranking minority member, Mr. Walker, for any general remarks before we move to the first bill, which is the National Science Foundation Act.

Bob?

Mr. WALKER. Mr. Chairman, I don't have any real opening remarks. I prefer to move on to the NSF bill, where I will have some remarks.

Mr. BROWN. All right. Let's proceed, then, to the NSF bill, H.R. 2282.

I might say that Congress, in 1988, passed for the first time a multi-year authorization for NSF. This five-year authorization law endorsed the proposal from the Administration at that time to double the NSF budget over five years. The Research and Education Programs supported by NSF are critical to the future well-being of the Nation, and the committee supported a significant funding increase for NSF to allow the Foundation to meet the expanding research opportunities in many fields of science and engineering, to address shortcomings in the academic research infrastructure, and to improve science education at all levels of instruction, thereby underpinning the entire R&D enterprise.

Although NSF has experienced moderate growth over the past three years, the tight fiscal situation has prevented appropriation levels from reaching the growth rates in the current authorization law. H.R. 2282 proposes to readjust the overall NSF authorization levels and to authorize scientific directorate programs for fiscal year 1992 and fiscal year 1993 that were not included in the 1988 act.

The Science Subcommittee chairman, Mr. Boucher, will describe the provisions in the bill, and I'll recognize Mr. Boucher at this time.

[The prepared statement of Mr. Brown follows:]

STATEMENT
BY THE
HON. GEORGE E. BROWN, JR., (D-CA)
ON
MARKUP OF H.R. 2282, THE NATIONAL SCIENCE FOUNDATION AUTHORIZATION ACT AMENDMENTS OF 1991

May 22, 1991

IN 1988, CONGRESS PASSED, FOR THE FIRST TIME, A MULTI-YEAR AUTHORIZATION FOR THE NATIONAL SCIENCE FOUNDATION (NSF). THIS FIVE-YEAR AUTHORIZATION LAW ENDORSED THE PROPOSAL FROM THE ADMINISTRATION AT THAT TIME TO DOUBLE THE NSF BUDGET OVER FIVE YEARS.

THE RESEARCH AND EDUCATION PROGRAMS SUPPORTED BY NSF ARE CRITICAL TO THE FUTURE WELL-BEING OF THE NATION. THE COMMITTEE SUPPORTED A SIGNIFICANT FUNDING INCREASE FOR NSF TO ALLOW THE FOUNDATION TO MEET THE EXPANDING RESEARCH OPPORTUNITIES IN MANY FIELDS OF SCIENCE AND ENGINEERING, TO ADDRESS

SHORTCOMINGS IN THE ACADEMIC RESEARCH INFRASTRUCTURE, AND TO IMPROVE SCIENCE EDUCATION AT ALL LEVELS OF INSTRUCTION, THEREBY UNDERPINNING THE ENTIRE R&D ENTERPRISE.

ALTHOUGH NSF HAS EXPERIENCED MODERATE GROWTH OVER THE PAST THREE YEARS, THE TIGHT FISCAL SITUATION HAS PREVENTED APPROPRIATION LEVELS FROM REACHING THE GROWTH RATES IN THE CURRENT AUTHORIZATION LAW. H.R. 2282 PROPOSES TO READJUST THE OVERALL NSF AUTHORIZATION LEVELS AND TO AUTHORIZE SCIENTIFIC DIRECTORATE PROGRAMS FOR FY 1992 AND FY 1993 THAT WERE NOT INCLUDED IN THE 1988 ACT. THE SCIENCE SUBCOMMITTEE CHAIRMAN, MR. BOUCHER, WILL DESCRIBE THE PROVISIONS IN THE BILL.

Mr. **Boucher**. Thank you, Mr. Chairman.

I have a prepared statement, and I ask unanimous consent that that be made a part of the record.

Mr. **Brown**. Without objection.

[The prepared statement of Mr. Boucher follows:]

STATEMENT
BY THE
HON. RICK BOUCHER, (D-VA)
ON
MARKUP OF H.R. 2282, THE NATIONAL SCIENCE FOUNDATION AUTHORIZATION ACT AMENDMENTS OF 1991

May 22, 1991

On May 2, 1991, the Subcommittee on Science marked up a draft bill to amend the NSF Authorization Act of 1988. The bill, as ordered reported by the Subcommittee, was subsequently introduced on May 9, as H.R. 2282.

The principal purpose of H.R. 2282 is to authorize appropriations for NSF scientific directorates for FY 1992 and FY 1993. The current NSF authorization law, which extends through FY 1993, includes an authorization for Research and Related Activities for FY 1992 and FY 1993, but not for the individual directorates within Research and Related Activities.

H.R. 2282 also lowers the total NSF authorization levels currently in statute for FY 1992 and FY 1993. The current law authorizes approximately $500 million more than the President's request for FY 1992. The difference is due both to the rate of *budget growth authorized in the five-year authorization law, which would have allowed doubling of the NSF budget between FY 1987 and FY 1992, and also to providing an authorization of $250 million per year for the Academic Research Facilities Modernization program.*

H.R. 2282 authorizes $2.72 billion for NSF in FY 1992, the level of the President's request, which is 17.5 percent above the FY 1991 appropriation level. Within the total authorization, the bill reallocates $40 million for the Academic Research Facilities Modernization program, for which no funds were requested. The serious problem of deterioration of academic research facilities is well documented. The NSF program, which was funded at $20 million in each of the past two years, ought to be sustained and strengthened rather than eliminated.

Of the resources allotted to the facilities program, $24 million came from a prohibition on construction of the Laser Interferometer Gravitational Wave Observatory, called LIGO. The prohibition on construction of LIGO for FY 1992 does not extend *to laboratory research or to design studies related to LIGO. The intention of the provision is to require NSF to reconsider the timeliness of proceeding with full scale development of this $200 million project, especially in light of the recent National Academy of Sciences astronomy survey report. The Academy's report did not endorse LIGO. It placed instead high priority on the repair and maintenance of existing astronomy facilities. In the draft Committee views in the Subcommittee report on H.R. 2282, we have asked the National Science Board to reconsider and report back to the Committee on the priority that should be given to LIGO construction at this time.*

For FY 1993, H.R. 2282 lowers the NSF authorization now in the statute to $3.07 billion, the level of NSF's three-year budget projection which was submitted to Congress with the President's FY 1992 budget request. This funding level provides an increase of 14 percent for Research and Related Activities and an increase of 12.7 percent for Education and Human Resources above the FY 1992 authorization levels in the bill. Finally, an increase of 10 percent is provided for the Academic Research Facilities

Modernization program.

Parallel with development of the NSF authorization act amendments, the Subcommittee on Science has been working on legislation to address indirect cost recovery by academic institutions performing federally funded research. Although we will pursue comprehensive legislation standardizing indirect cost provisions for all federal research funding agencies, I intend to offer an amendment to H.R. 2282 to regulate indirect cost recovery under NSF's research grants. This action is being taken because of the importance of quickly restoring public confidence regarding the expenditure of federal research funds, and to expedite consideration of this NSF authorization bill. The comprehensive bill would amend this bill as well as any other authorization bill which includes an indirect cost provision.

H.R. 2282 endorses the most recent plan of the Administration to complete doubling of the NSF budget by FY 1994 using FY 1987 as the base year, strengthens the research programs, which have seen little real growth over the past few *years; sustains growth of education activities; and provides for modest, but highly leveraged, research facilities modernization and research instrumentation programs. I am pleased to commend this bill to the Committee for its consideration.*

Mr. BOUCHER. Mr. Chairman, H.R. 2282 authorizes appropriations for the National Science Foundation's scientific directorates for fiscal years 1992 and 1993. The general authorization for the NSF extends through fiscal year 1993, but it does not contain line specific authorizations for the scientific directorates, and the goal of H.R. 2282 is to provide those line specific authorizations. The bill lowers the total NSF authorization level for fiscal years 1992 and 1993 to reflect the current rate of growth in appropriations for the agency and to reflect the Administration's budget request for fiscal year 1992, which is itself a 17.5 percent increase over the appropriation level for fiscal year 1991.

The bill also affects a number of specific programs within the National Science Foundation. It removes $24 million for construction of the Gravitational Wave Observatory, which is known as LIGO, but it specifically encourages further laboratory research and design studies for that facility, and in doing so, it reflects the recommendations of the Astronomy Survey Report of the National Academy of Sciences, which suggests that construction of LIGO is premature at this time.

The bill also provides $40 million for academic research facilities modernization and construction. This is a very popular program. The hearings before the subcommittee revealed a continuing need for funding of that program. The Administration had requested no monies for it for fiscal year 1992; our bill provides $40 million. It also provides $33.5 million for the Administration's new initiative in research instrumentation.

With regard to indirect costs, I would offer several comments, Mr. Chairman. The subcommittee is structuring at the present time broad legislation that is designed to address indirect cost recovery with respect to Federal funding of research at academic institutions. While we intend to pursue comprehensive legislation that would apply to all Federal agencies that fund research—and that is a collaborative effort with other committees having authorizing jurisdiction — this morning I intend to offer an amendment that would regulate indirect cost recovery under the research grants funded by the National Science Foundation. I think it's important that that be done in order to restore public confidence in the indirect cost recovery process and also to expedite consideration of this reauthorization measure.

I will say, Mr. Chairman, that we have worked very actively with the Republican leadership of both the subcommittee and the full committee in structuring this amendment, which I will offer in regular course when we reach that point in the agenda.

Mr. Chairman, it's my pleasure to commend this reauthorization measure to the committee for its consideration, and I would be pleased to yield to the ranking Republican member of the Science Subcommittee, the gentleman from California, Mr. Packard, for his comments.

[A copy of H.R. 2282, and Subcommittee Report on H.R. 2282 follow:]

I

102D CONGRESS
1ST SESSION

H. R. 2282

To amend the National Science Foundation Authorization Act of 1988, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

MAY 9, 1991

Mr. BOUCHER (for himself, Mr. PACKARD, Mr. BROWN, Mr. BRUCE, Mr. BOEHLERT, Mr. KOPETSKI, Mr. FAWELL, Mr. VALENTINE, Mr. SCHIFF, Mr. NAGLE, Mr. GILCHREST, Mr. HAYES of Louisiana, Mr. BROWDER, Mr. THORNTON, Mr. ROEMER, Mrs. COLLINS of Michigan, Mr. BACCHUS, and Mr. MCNULTY) introduced the following bill; which was referred to the Committee on Science, Space, and Technology

---

A BILL

To amend the National Science Foundation Authorization Act of 1988, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "National Science Foundation Authorization Act Amendments of 1991".

SEC. 2. AUTHORIZATION OF APPROPRIATIONS.

(a) FISCAL YEAR 1992.—Section 101(e) of the National Science Foundation Authorization Act of 1988 is amended to read as follows:

"(e) There are authorized to be appropriated to the Foundation $2,722,000,000 for fiscal year 1992, which shall be available for the following categories:

"(1) Research and Related Activities, $1,940,000,000, which shall be available for the following subcategories:

"(A) Mathematical and Physical Sciences, $626,580,000.

"(B) Engineering, $247,700,000.

"(C) Biological, Behavioral, and Social Sciences, $355,640,000.

"(D) Geosciences, $419,540,000.

"(E) Computer and Information Science and Engineering, $229,500,000.

"(F) Scientific, Technological, and International Affairs, $61,040,000.

"(2) Education and Human Resources, $390,000,000.

"(3) United States Antarctic Program, $193,000,000.

"(4) Academic Research Facilities Modernization Program, $40,000,000.

"(5) Academic Research Instrumentation Program, $33,500,000.

"(6) Salaries and Expenses, $122,000,000.

"(7) Office of Inspector General, $3,500,000.".

(b) FISCAL YEAR 1993.—Section 101(f) of the National Science Foundation Authorization Act of 1988 is amended to read as follows:

"(f) There are authorized to be appropriated to the Foundation $3,068,000,000 for fiscal year 1993, which shall be available for the following categories:

"(1) Research and Related Activities, $2,210,000,000, which shall be available for the following subcategories:

"(A) Mathematical and Physical Sciences, $731,460,000.

"(B) Engineering, $278,325,000.

"(C) Biological, Behavioral, and Social Sciences, $400,400,000.

"(D) Geosciences, $472,665,000.

"(E) Computer and Information Science and Engineering, $258,790,000.

"(F) Scientific, Technological, and International Affairs, $68,360,000.

"(2) Education and Human Resources, $439,000,000.

"(3) United States Antarctic Program, $210,000,000.

"(4) Academic Research Facilities Modernization Program, $43,000,000.

"(5) Academic Research Instrumentation Program, $36,000,000.

"(6) Salaries and Expenses, $126,000,000.

"(7) Office of Inspector General, $4,000,000.".

(c) LIMITATION.—Section 101 of the National Science Foundation Authorization Act of 1988 is amended by adding at the end the following new subsection:

"(i) Of the amount authorized in subsection (e), no funds shall be available for construction of the Laser Interferometer Gravitational Wave Observatory. This limitation shall not apply to expenditure of funds for research activities or design studies associated with such project.".

SEC. 3. ADMINISTRATIVE AMENDMENTS.

Section 5(e) of the National Science Foundation Act of 1950 (42 U.S.C. 1864) is amended by striking the last sentence of paragraph (2).

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Subcommittee Report on H.R. 2282, the National Science Foundation Authorization Act Amendments

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I. Summary

Purpose of the Bill

The principal purpose of the bill is to authorize appropriations for the National Science Foundation (NSF) scientific directorates for FY 1992 and FY 1993. The NSF Authorization Act of 1988 (P.L. 100-570), which is amended by H.R. 2282, provides an authorization of appropriations for Research and Related Activities (R&RA) for FY 1992 and FY 1993 but not for the individual scientific directorates that comprise R&RA. H.R. 2282 also lowers the total authorization level for NSF for FY 1992 and FY 1993. The NSF Authorization Act of 1988 established the Academic Research Facilities Modernization program, with an authorized funding level of $250 million per year for FY 1992 and FY 1993, and authorized doubling of the total NSF budget by FY 1992, on the basis of the FY 1987 budget level. Due to the failure of appropriations to achieve the authorization levels for the past three fiscal years, the P.L. 100-57 authorization about $500 million above the President's request for FY 1992.

Budget Explanation

H.R. 2282 authorizes appropriations to NSF for FY 1992 in the amount of $2,722,000,000 and for FY 1993 in the amount of $3,068,000,000 as follows:

Budget Activities - Authorization FY 1992

Research and Related Activities:	
Mathematical and Physical Sciences	626,580,000
Engineering	247,700,000
Biological, Behavioral, and Social Sciences	355,640,000
Geosciences	419,540,000
Computer and Information Sciences and Engineering	229,500,000
Scientific, Technological, and International Affairs	61,040,000
Subtotal	**1,940,000,000**
Education and Human Resources	390,000,000
United States Antarctic Program	193,000,000
Academic Research Facilities Modernization Program	40,000,000
Academic Research Instrumentation Program	33,500,000
Salaries and Expenses	122,000,000
Office of the Inspector General	3,500,000
Total	**2,722,000,000**

Budget Activities - Authorization FY 1993

Research and Related Activities:	
Mathematical and Physical Sciences	731,460,000
Engineering	278,325,000
Biological, Behavioral, and Social Sciences	400,400,000
Geosciences	472,665,000
Computer and Information Sciences and Engineering	258,790,000
Scientific, Technological, and International Affairs	68,360,000
Subtotal	**2,210,000,000**
Education and Human Resources	439,000,000
United States Antarctic Program	210,000,000
Academic Research Facilities Modernization Program	43,000,000
Academic Research Instrumentation Program	36,000,000
Salaries and Expenses	126,000,000
Office of the Inspector General	4,000,000
Total	**3,068,000,000**

FY 1992

The total authorization for NSF in FY 1992 is at the level of the President's budget request. In addition, the authorizations for Education and Human Resources, United States Antarctic Program, Salaries and Expenses, and Office of Inspector General are identical to the President's request, as shown in Fig. 1.

R&RA is reduced below the President's request by $23.5 million, which is taken from the Mathematical and Physical Sciences directorate budget activity. The remaining scientific directorate authorizations within R&RA are at the President's request level. The $23.5 million is the amount proposed in the President's budget for construction of the Laser Interferometer Gravitational Wave Observatory (LIGO). The bill prohibits construction, but not research or design activities, associated with LIGO for FY 1992.

The final two authorizations are for the Academic Research Facilities Modernization Program, $40 million, and Academic Research Instrumentation Program, $33.5 million. The President's budget request included no funding for the former and $50 million for the latter program.

FY 1993

The authorizations for FY 1993 are based on NSF's three-year budget projection, submitted to Congress at the time of the President's FY 1992 budget request. The three-year projection assumes the NSF budget doubling will be achieved by FY 1994. Comparisons between H.R. 2282 and the three-year projection for individual budget activities are shown in Fig. 1.

The total authorization for NSF is identical to the NSF projection, an increase of 13.4% above the FY 1992 authorization. R&RA is increased by 13.9%, rather than 15.3% as in the three-year projection, with increases in the scientific directorates proportional to the three-year projection levels. Education and Human Resources is increased by 12.7%, rather than 6.4% as in the three-year projection. The Academic Research Facilities Modernization program is increased by 10% and the Academic Research Instrumentation Program by 7.4%.

Authorizations for the United States Antarctic Program, Salaries and Expenses, and the Office of Inspector General are identical to the three-year projection.

II. Subcommittee Actions

The Subcommittee held three days of authorization hearings on NSF, and the full Committee held a posture hearing on NSF.

On February 20, 1991, the NSF Acting Director and the Chairman of the National Science Board presented the FY 1992 budget request including a discussion of the overall balance among types of programs and proposals for significant program augmentations and for new initiatives. On March 12, 1991, representatives from the academic community presented views on the overall NSF budget and program proposals for FY 1992, and a panel of witnesses representing State educational agencies reviewed NSF activities in support of improvement of science and math education in primary and secondary schools. On March 13, 1991, panels of academic and industrial scientists commented on three specific NSF program areas: the research instrumentation and research facilities modernization programs, the Laser Interferometer Gravitational Wave Observatory (LIGO), and the initiative on materials synthesis and processing. Finally, on April 11, 1991, the new NSF Director, Dr. Walter Massey, appeared before the full Committee to present his views on the state of NSF and his vision for the future of the Foundation.

The hearings highlighted broad support for the NSF budget proposal for FY 1992. The proposed budget will allow NSF to develop new initiatives in high-performance computing and materials science and to augment existing efforts in global change research. The proposal provides substantial increases for science education programs and will allow NSF to strengthen individual investigator awards in the core research programs. The principal criticism raised by non-federal witnesses was the failure of NSF to request funding for the Academic Research Facilities Modernization Program.

On May 2, 1991, the Subcommittee met to markup a draft NSF authorization bill offered by Chairman Boucher. Mr. Packard offered an amendment which was intended to bring the FY 1993 authorization level to the level of the Administration's three-year budget projection for NSF. The amendment reduced the total NSF authorization level in FY 1993 by $2 million, removing $1 million from the Academic Research Facilities Modernization Program which still funds the program at $43 million over the Administration's estimate. The amendment also reduced the Education and Human Resources Directorate by $1 million, which still allows a 5.8 percent increase over the estimate for FY 1993. (See Fig. 1). The amendment was approved by voice vote, and the draft bill, as amended, was approved and ordered reported.

The draft bill, as amended, was introduced by Mr.Boucher on May 9, 1991, including as cosponsors Mr. Packard and 16 other Members.

III. Explanation of H.R. 2282

H.R. 2282 amends the current NSF authorization law (P.L. 100-570), which extends through FY 1993. The existing law, the first multi-year NSF authorization, endorsed the proposal by two Administrations to double the NSF budget over five years, with FY 1987 as the base year. Due to uncertainties in estimating the needs of the individual scientific directorates in the fourth and fifth years, the Congress did not include specific directorate authorizations, beyond the overall authorization for Research and Related Activities, in those years. H.R. 2282 adds authorizations for the scientific directorates and adjusts the total NSF authorizations for the two fiscal years to adjust the authorization increases to reflect the current fiscal situation.

Section 2(a) authorizes appropriations for FY 1992. The bill endorses the Administration's budget request in large part. The main Subcommittee action was to include an authorization of $40 million for the Academic Research Facilities Modernization Program, for which no funding request was made in the Administration's request. The rationale for this action is discussed in the draft Committee Views. The funds for the facilities program were obtained by a reduction of $23.5 million in the Mathematical and Physical Sciences and a reduction of $6.5 million in the Academic Research Instrumentation budget activities. The reason for the former action is discussed in the draft Committee Views. The reduction in the instrumentation program is not intended to imply that the funding level proposed was excessive but simply reflects the importance the Subcommittee attaches to the facilities program. The Subcommittee also views the two programs as connected since many modern instruments cannot function in inadequate laboratory spaces.

The authorization level for FY 1992 will provide an increase of $406 million above the FY 1991 appropriation. This budget growth will allow NSF to strengthen individual investigator support for the core research programs and sustain vigorous support for educational activities. In addition, the budget will allow NSF to make significant contributions to interagency research initiatives in high-performance computing and global change research, as well as initiate a new cross-directorate research program on materials synthesis and processing.

Section 2(b) authorizes appropriations for FY 1993. The total authorization level is identical to the NSF three-year budget projection required by statute to be submitted to Congress with the FY 1992 budget request. The budget projection would lead to doubling of the NSF budget by FY 1994 using FY 1987 as the base year. Relative to the three-year projection, the bill reduces growth in R&RA by 1.5 percent in order to increase the growth in Education and Human Resources from 6.4 percent to 12.7 percent and to provide 10 percent growth in the research facilities program.

Section 2(c) prohibits construction of LIGO in FY 1992. No prohibition is applied to research activities or design studies associated with LIGO. This action is discussed in the draft Committee Views.

Section 3 is a technical amendment to the NSF Act of 1950. The purpose is to strike the last sentence of paragraph (2) of subsection 5(e) of the Act. This action removes a sunset provision on the subsection which specifies the relationship between the National Science Board and the NSF Director relative to the authority of NSF to make grants, contracts, and other contractual arrangements. The original language, unintentionally, was a sunset provision for the entire subsection rather than for paragraph (2). Paragraph (2) provided some limitations on delegation authority of the Board contained in paragraph (1) and required a biennial report explaining delegation actions taken. The Subcommittee believes that the provisions of paragraph (2) are valuable and ought to stay in force.

IV. Section Analysis of H.R. 2282, As Reported

A bill to authorize appropriations for activities of the National Science Foundation (NSF) for fiscal years 1992 and 1993.

Section 1.-Cites the Act's title as the "National Science Foundation Authorization Act Amendments of 1991".

Section 2(a).-Section 101(e) of the National Science Foundation Authorization Act of 1988 is amended to authorize an appropriation of $2,722,000,000 to the NSF for fiscal year 1992, in the following categories:

1.	Research and Related Activities within Areas defined by items 2-7	$1,940,000,000
2.	Mathematical and Physical Sciences	626,580,000
3.	Engineering	247,700,000
4.	Biological, Behavioral, and Social Sciences	355,640,000
5.	Geosciences	419,540,000
6.	Computer and Information Sciences and Engineering	229,500,000
7.	Scientific, Technological, and International Affairs	61,040,000
8.	Education and Human Resources	390,000,000
9.	United States Antarctic Program	193,000,000
10.	Academic Research Facilities Modernization Program	40,000,000
11.	Academic Research Instrumentation Program	33,500,000
12.	Salaries and Expenses	122,000,000
13.	Office of the Inspector General	3,500,000

Section 2(b).-Section 101(f) of the National Science Foundation Authorization Act of 1988 is amended to authorize an appropriation of $3,068,000,000 to NSF for fiscal year 1993, in the following categories:

1.	Research and Related Activities within Areas defined by items 2-7	$2,210,000,000
2.	Mathematical and Physical Sciences	731,460,000
3.	Engineering	278,325,000
4.	Biological, Behavioral, and Social Sciences	400,400,000
5.	Geosciences	472,665,000
6.	Computer and Information Sciences and Engineering	258,790,000
7.	Scientific, Technological, and International Affairs	68,360,000
8.	Education and Human Resources	439,000,000
9.	United States Antarctic Program	210,000,000
10.	Academic Research Facilities Modernization Program	43,000,000
11.	Academic Research Instrumentation Program	36,000,000
12.	Salaries and Expenses	126,000,000
13.	Office of the Inspector General	4,000,000

Section 2(c).-Amends Section 101 of the National Science Foundation Act of 1988 by adding a new subsection. This subsection prohibits the use of amounts authorized for FY 1992 in subsection (e) for construction of the Laser Interferometer Gravitational Wave Observatory. However, this prohibition does not apply to the expenditure of funds for research activities or design studies associated with the project.

Section 3.-Amends section 5(e) of the National Science Foundation Act of 1950 by striking out the last sentence of paragraph (2).

V. Draft Committee Views

1. Academic Research Facilities Modernization Program

Background

Deterioration of academic research facilities has received much attention over the past several years. The dimensions of the problem were highlighted in a 1986 report of the White House Science Council entitled, "A Renewed Partnership". This report estimated that $10 billion over ten years would be needed to refurbish academic research facilities. An NSF survey from the same year revealed that more than 80 percent of research administrators at doctorate-granting universities reported that outmoded research facilities limited the scope of research that could be carried out. The most recent NSF survey has indicated that the amount of deferred repair, maintenance, and new construction for research facilities in U.S. academic institutions has increased 40 percent from 1988 to 1990, to a level of approximately $12 billion.

Lack of adequate facilities limits the kinds of research that can be undertaken and, ultimately, will prevent academic institutions from staying at the forefront of knowledge. Obsolescence or unavailability of facilities will not only result in missed research opportunities but will also prevent development of first-rate faculty and graduate students. The erosion of the academic research environment will deflect the best students from academic careers.

As one response to the serious facilities problem, the Congress incorporated the Academic Research Facilities Modernization Program as title II of the NSF Authorization Act of 1988 (P.L. 100-570). In the first competition under the program, NSF received more than 425 proposals requesting a total of $320 million. From appropriations of $20 million in each of FY 1990 and FY 1991, NSF made awards to 78 universities, colleges, and nonprofit institutions in 37 states. The $40 million provided by the awards was augmented by $61 million in matching funds from the various non-federal sources. Therefore, the program leveraged $3 in non-federal resources for every $2 awarded.

Committee View

The Committee deplores the absence in the FY 1992 NSF budget request of funding for the Academic Research Facilities Modernization Program. The program addresses a serious problem that threatens to undermine first rate academic research. The program is widely supported by the academic community and has been strongly endorsed by Congress.

The initial competition for the program attracted an enthusiastic response from educational institutions and resulted in significant leveraging of federal funds. Even though the total magnitude of the facilities problem greatly exceeds the current scale of this program, the Committee finds it difficult to understand why NSF's response has been to eliminate the program, particularly in a budget request 17.5 percent above the preceding year's appropriation level.

In light of the manifest need for refurbishment of academic research facilities, the Committee has authorized $40 million for the program for FY 1992 and $43 million for FY 1993. The reduction in the authorization relative to the current NSF authorization law does not reflect a diminished priority for the program but rather reflects the fiscal realities of today. The Committee does not endorse the cuts in disciplinary research programs and education activities that would be required in order to fund the facilities program at the $250 million per year level in the current authorization law. However, the facilities program should be sustained and allowed to grow, consistent with overall growth in the Foundation's budget. The Committee strongly encourages NSF to plan for, advocate and maintain the facilities funding as an on-going program.

2. Laser Interferometer Gravitational-Wave Observatory (LIGO)

Background

LIGO is a proposed astronomical facility dedicated to the detection of cosmic gravitational waves. Gravitational radiation, or gravity waves, are generated during fast accelerations of massive celestial objects, such as black holes or neutron stars. The effect of a passing gravitational wave is a momentary, extremely small change in the apparent distance between two points. To illustrate the magnitude of this effect, a strong gravitational wave would briefly change the distance between two points 2400 trillion miles apart (one million times the distance to Neptune) by less than the thickness of a human hair.

The measurement techniques proposed to detect the tiny deflections due to passing gravity waves are based on laser interferometry. The proposed LIGO consists of two identical, widely separated detectors. Two detectors are needed in order to distinguish between the effects of gravity waves and anomalous signals that might be due to some local seismic disturbance, for example. Each detector is "L" shaped with equal length legs comprised of four-foot diameter, 2.5 mile-long vacuum pipes with weights suspended at the ends of the pipes. A laser beam is divided by an optical beam splitter into two separate beams which travel down different legs of the "L", are reflected back by mirrors attached to the weights, and then recombine in the beam splitter. If the distances between the weights are identical, the two beams cancel; but, if the beams travel different distances, an interference effect occurs, which reveals information characterizing the gravitational wave causing the change in length of the legs of the "L". If more than two detectors are built, the location in space of the source of the gravity waves could also be determined and, therefore, the multiple detectors could function like a telescope for studying cosmic events.

Research and development of interferometric gravitational-wave detectors started in the late 1960's. Beginning in 1979, NSF began funding specific interferometer projects at Caltech and MIT; and, in 1984, the National Science Board approved project planning and feasibility studies for a joint effort by Caltech and MIT to develop and operate a LIGO facility.

In 1990, the National Science Board approved the LIGO project, and the NSF included funding for constructing the two facilities in its 1991 budget request. Funds were not appropriated. The NSF FY 1992 budget includes a $23.5 million request to begin construction of LIGO, which is estimated to cost a total of $211 million and require five years to construct.

In 1986, the International Committee on General Relativity and Gravitation endorsed plans for kilometer-scale laser-interferometer gravitational wave detectors, one set in Europe and a second in the United States. At this time, the European and United States LIGO designs differ and no international agreement exists to construct a common design, with one detector on each continent as the initial step.

Committee View

For FY 1992, the Committee endorses the expenditure of funds for research activities or design studies associated with the LIGO project. However, in FY 1992, no funds are authorized by the Committee for construction of LIGO.

The Committee does not question the scientific value of research associated with the demanding task of detection of gravitational waves and has not made a final determination as to whether, or when, LIGO ought to proceed to full scale construction. However, the Committee does have questions about the priority that ought to be assigned to LIGO construction at this time.

LIGO was proposed as both a physics experiment and as an astronomical facility. While physicists doing research in gravitation have generally supported the project, the Committee notes that the National Research Council report (NRC), "Physics Through the 1990s", stated that the Long-Baseline Gravitational-Wave Facility, as LIGO was then named, should be supported "... assuming that other ongoing work of high quality will not be adversely affected." This statement implies that this facility was not considered to be the first priority.

Every ten years the astronomy and astrophysics community prioritizes facilities needs for the coming decade. The most recent NRC astronomy survey report, "The Decade of Discovery in Astronomy and Astrophysics", released in March 1991, does not include LIGO among its recommendations. For ground-based astronomy, the report assigned highest priority to maintaining and upgrading existing national research facilities operated by NSF. The report characterizes the astronomy research infrastructure as having deteriorated seriously in the last decade and estimates that a budget increase of $15 million per year is needed in order to take necessary remedial actions. In addition, the report recommends an increase of $10 million per year to restore NSF support for individual research grants in astronomy and astrophysics.

Testimony at an NSF authorization hearing before the Subcommittee on Science on March 13, 1991 raised questions about the adequacy of measurement accuracy of LIGO, as proposed, in detecting transient events associated with cosmic phenomena that may be expected to occur with reasonable frequency. The Committee understands that there is considerable uncertainty in estimating the level of sensitivity required. The question remains as to whether the accuracy of LIGO could be significantly increased through additional laboratory research prior to full scale development of the facility.

Finally, the Committee notes the absence of international collaboration in the construction of the first two facilities, which are required to verify the experimental technique. The Committee views LIGO as a highly appropriate scientific project for joint support with an international partner. Not only is the project of interest primarily to fundamental, non-targeted research, but it also requires the construction of widely separated facilities.

In light of the assessments of the previously discussed NRC reports, questions about the degree of readiness of the measurement technology to be employed in LIGO, the lack of international collaboration, and other budget priorities facing NSF, the Committee requests that the National Science Board reevaluate LIGO and reconsider the time at which LIGO construction ought to go forward. Specifically, the Committee requests that the National Science Board perform the review of LIGO and provide a report to the Committee by December 31, 1991, documenting the findings of that review.

If the National Science Board determines that construction of the project should proceed in FY 1993, the report should provide the basis for that decision and, if the project is recommended in part on the basis of its value as an astronomical observatory, should explain why greater priority has been assigned to the project than was assigned by the NRC Astronomy and Astrophysics Survey Committee. The Committee also requests that the National Science Board report describe any actions that NSF will take in response to the recommendations of the NRC astronomy survey report relative to refurbishment, operation and maintenance support for existing NSF national astronomy facilities.

3. Education and Human Resource Activities

Committee View

The Committee strongly endorses the proposed budget increase of 23 percent above the FY 1991 appropriation level for science and engineering education and for development of human resources in science and engineering in FY 1992. The Committee is pleased that significant increases are provided for all levels of instruction: precollege, undergraduate and graduate. This comprehensive approach is necessary to address important needs and deficiencies in science education and to expand interest in science and math among students at the precollege and undergraduate levels.

The Committee notes that resource allocations for undergraduate activities are nearly equally divided between programs in the Education and Human Resources (EHR) Directorate and in the several scientific directorates. The Committee does not object to this management arrangement but calls attention to the importance of strong coordination among these directorates' education activities. The Division of Undergraduate Science, Engineering, and Mathematics Education is the focal point for this coordination. The Committee expects the Director to ensure that this coordinating responsibility is diligently discharged.

Graduate students in science, math and engineering are a potential resource for improving science and math education at the secondary school level. The Committee requests that NSF study the possibility of a program of grants to support graduate students in teaching, or serving as a resource to teachers of, science or math. The study should explore whether such a program is feasible and would be effective. The Committee also requests that NSF provide the Committee with a report on the findings of the study.

For FY 1993, the bill provides an increase of 12.7 percent for EHR rather than 6.4 percent, as included in the NSF three-year budget projection. Most of the resources in EHR are for precollege programs, which the Committee believes have not yet achieved funding levels necessary to address the serious problems confronting science and math education in the schools. The Committee intends to restore funding to EHR to achieve at least the levels, in constant dollars, of the late 1960's.

4. Interagency Research Initiatives

Committee View

The Committee endorses NSF participation in the U.S. Global Change Research Program and the High Performance Computing and Communications Program. The Committee has long advocated establishment of a process to identify research needs in areas of national importance and to formulate coordinated R&D activities across several agencies to achieve the identified goals.

In formulating its role within a particular interagency initiative, NSF senior management presumably reviews the directorate research programs and identifies which disciplinary activities should participate in the initiative. The Committee notes that, for the High-Performance Computing and Communications Program, almost the entire NSF contribution comes from programs within the Computer Science and Engineering (CISE) Directorate. Since an important aspect of this interagency program is computational research focused on grand challenge problems in many fields of science and engineering, it is not clear why CISE is the only NSF directorate participating.

The Committee requests that NSF provide, as soon as possible, a brief explanation of the planning process within NSF for determining which NSF activities will participate in a particular interagency research initiative. Also, the Committee requests clarification on the reasons for the apparent lack of participation of directorates other than CISE in the high-performance computing initiative.

5. Three-year Budget Estimate

Background

The NSF Authorization Act of 1988 amended the NSF Act of 1950 to require that NSF submit to Congress, each year, a three-year budget estimate at the time of the annual submission of the President's budget. The Committee's report on oversight of NSF FY 1990 programs (H. Rept 101-309) reviewed the first submission under this requirement and found it lacking in useful information regarding program priorities in the out-years. The Committee requested that future three-year estimates include an explanation and rationale for funding trends in the various budget categories and subcategories. The second and third three-year estimates submitted again provided no information on relative priorities in the last two years of the estimates and did not include the requested explanation and rationale for the estimated funding levels presented.

Committee View

The Committee again points out that, in the absence of meaningful out-year estimates of budget trends, multi-year authorizations are unlikely to be approved in the future. The Committee is aware that estimates of future budget requirements are uncertain and subject to change as unexpected research opportunities emerge or as special interagency programs are endorsed by the Administration. However, in general, broad priorities across program areas ought to be available due to the relatively long time scales associated with basic research projects. At the very least, the three-year projections should include discussion of new initiatives in promising research areas that are likely to emerge in future budgets. The Committee needs more useful information to better understand NSF's future plans and intentions.

VI. Subcommittee Recommendation

A quorum being present, the Subcommittee Print, as amended, was ordered reported on May 2, 1991, by a voice vote of the Subcommittee on Science, and was subsequently introduced as H.R. 2282 on May 9, 1991.

Figure 1. National Science Foundation Budget Comparisons: Actions by the Committee on Science, Space, and Technology

[in millions of dollars]*

Activities	Current FY 1991	Fiscal Year 1992			Fiscal Year, 1993		
		Admin. Req.	Comm. Rec. H.R. 2282	Changes from Admin. Req.	Admin. Req.**	Comm. Rec. H.R. 2282	Changes from Admin. Req.
Research and Related Activities							
Biological, Behavioral, and Social Sciences	315	356	356	0	410	400	-10
Computer and Information Science and Engineering	186	230	230	0	265	259	-6
Engineering	216	248	248	0	285	278	-7
Geosciences	368	420	420	0	484	473	-11
Mathematical and Physical Sciences	558	650	627	-24	749	731	-18
Scientific, Technological, and International Affairs	51	61	61	0	70	68	-2
Subtotal	1694	1964	1940	-24	2263	2210	-53
Education and Human Resources	322	390	390	0	415	439	+24
U.S. Antarctic Program	175	193	193	0	210	210	0
Academic Research Facilities Modernization Program	20	0	40	+40	0	43	+43
Academic Research Instrumentation Program	0	50	34	-16	50	36	-14
Salaries and Expenses	101	122	122	0	126	126	0
Office of the Inspector General	3	4	4	0	4	4	0
Total	2316	2722	2722	0	3068	3068	0

* Dollar amounts have been rounded

** NSF three year budget estimate

6. Experimental Program to Stimulate Competitive Research (EPSCoR)

Background

The Experimental Program to Stimulate Competitive Research (EPSCoR) is a merit-based program designed to improve the scientific and technological capacities of states with less-developed research infrastructures. By setting aside money for worthy projects in these states, the program helps to build a thriving scientific and technological base across the United States. EPSCoR, which was initiated by this Committee in 1978 and expanded at the instigation of this Committee in 1985, currently funds research in 16 states (Arkansas, Maine, Montana, South Carolina, West Virginia, Alabama, Kentucky, Nevada, North Dakota, Oklahoma, Vermont, Wyoming, Idaho, Louisiana, Mississippi, and South Dakota) and the Commonwealth of Puerto Rico. In FY 1991 Nebraska and Kansas were added to EPSCoR, and they will become eligible to receive research awards in FY 1992.

In FY 1991 EPSCoR has begun an advanced development competition among the 17 current states (including Puerto Rico) in which up to ten will receive awards of up to $1.5 million annually for three years.

Committee View

Since its inception EPSCoR has made great strides towards developing the research infrastructure of these states. The Committee wholeheartedly endorses the program because the future economic development of the United States depends upon building a truly *national* scientific and technical infrastructure. As the May 1991 Office of Technology Assessment report *Federally Funded Research: Decisions for a Decade* notes, "Regional and institutional capacity are important concerns in all Federal funding, and encouraging new institutional participants and development of research centers strengthens the future capacity and diversity of the research system." EPSCoR works toward this objective by ensuring that a pool of money is available for merit-based awards for proposals from states with a less-developed research base.

Unfortunately, EPSCoR's success to date has been tightly circumscribed by the size of its budget. The program seeks to fund scientific projects in about one-third of the states with under seven-tenths of one percent of the NSF's Research and Related Activities account. Between FY 1991 and FY 1993 this account should grow by some 30%. The Committee is certain that this growth is large enough to accommodate the expansion of EPSCoR with ease.

Thus, the Committee urges the NSF to fund awards for one or more additional rounds of advanced development competition to take place in FY 1993. These rounds would give states which fail to receive awards in the first round an opportunity to refine and resubmit their proposals.

Additionally, the Committee is concerned that the $1.5 million cap on awards may not be enough to provide adequate funding for meritorious research in some of the EPSCoR states. It believes that the NSF should fund larger EPSCoR awards for these states -- but only when justified by their proposals.

Mr. **Packard**. Thank you.

Thank you, Mr. Chairman.

I commend you, Chairman Brown, for scheduling this markup which allows this committee's authorization for the National Science Foundation, the Environmental Protection Agency, and the Department of Energy to move to the floor in a timely manner.

I would like also to thank the chairman of the subcommittee, Mr. Boucher, for both his dedication and cooperation on the subcommittee.

I'm glad to report that the markup bill which came out of the subcommittee contains funding for fiscal year 1992 at the level requested by the President and funding for fiscal year 1993 at the level of the Administration's estimate. These increases represent the commitment to double the budget of the National Science Foundation by 1994.

The National Science Foundation conducts many exciting programs and initiatives which will be funded through this bill. These activities include, among other things, the high- performance computing initiative, research in the Antarctic, research into global changes. These initiatives and many others are, of course, of very high profile. It is important to remember, however, that the very core of the NSF revolves around education and research, and I believe that these vital areas have been adequately funded in this bill.

Because the bill authorizes funding at the level of the President's request and because the bill funds such important programs, I am proud to be a co-sponsor of the legislation, and I commend it to my colleagues on the full committee for approval.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Packard follows:]

STATEMENT OF
THE HONORABLE RON PACKARD (R-CA)
FULL COMMITTEE MARKUP
NATIONAL SCIENCE FOUNDATION AUTHORIZATION ACT AMENDMENTS OF 1991

10:00 A.M., 2318 RHOB
MAY 22, 1991

THANK YOU MR. CHAIRMAN

I COMMEND CHAIRMAN BROWN FOR SCHEDULING THIS MARKUP WHICH ALLOWS THIS COMMITTEE'S AUTHORIZATIONS FOR THE NATIONAL SCIENCE FOUNDATION, THE ENVIRONMENTAL PROTECTION AGENCY, AND THE DEPARTMENT OF ENERGY TO MOVE TO THE FLOOR IN A TIMELY MANNER. I WOULD ALSO LIKE TO THANK THE CHAIRMAN OF THE SUBCOMMITTEE ON SCIENCE, MR. BOUCHER, FOR BOTH HIS DEDICATION AND HIS COOPERATION ON THE SUBCOMMITTEE.

I AM GLAD TO REPORT THAT THE MARKED-UP BILL WHICH CAME OUT OF THE SUBCOMMITTEE CONTAINS FUNDING FOR FISCAL YEAR 1992 AT THE LEVEL REQUESTED BY THE PRESIDENT AND FUNDING FOR FISCAL YEAR 1993 AT THE LEVEL OF THE ADMINISTRATION'S ESTIMATE. THESE INCREASES REPRESENT THE COMMITMENT TO DOUBLE THE BUDGET OF THE NATIONAL SCIENCE FOUNDATION BY 1994.

THE NATIONAL SCIENCE FOUNDATION CONDUCTS MANY EXCITING PROGRAMS AND INITIATIVES WHICH WILL BE FUNDED THROUGH THIS BILL. THESE ACTIVITIES INCLUDE, AMONG OTHER THINGS, THE HIGH PERFORMANCE COMPUTING INITIATIVE; RESEARCH IN THE ANTARCTIC; AND RESEARCH INTO GLOBAL CHANGE. THESE INITIATIVES ARE, OF COURSE, VERY HIGH-PROFILE. IT IS IMPORTANT TO REMEMBER, HOWEVER, THAT THE VERY CORE OF NSF REVOLVES AROUND EDUCATION AND RESEARCH. I BELIEVE THESE VITAL AREAS HAVE BEEN ADEQUATELY FUNDED IN THIS BILL.

BECAUSE THE BILL AUTHORIZES FUNDING AT THE LEVEL OF THE PRESIDENT'S REQUEST AND BECAUSE THE BILL FUNDS SUCH IMPORTANT PROGRAMS, I AM PROUD TO BE A CO-SPONSOR OF THIS LEGISLATION.

Mr. **Brown**. Does any other member desire to be recognized for comments with regard to the National Science Foundation?

Mr. Walker?

Mr. **Walker**. Mr. Chairman, I want to add my support to this legislation. Mr. Packard and Mr. Boucher have worked hard to bring a responsible bill before the committee, and I want to commend their efforts, and also yours, in scheduling the bill before the full committee.

H.R. 2282 funds NSF at the President's request and at the same time reflects the committee's concerns and priorities. I want to thank Mr. Packard for his amendment at subcommittee to ensure that this is all done in a fiscally responsible fashion in the outyears. The National Science Foundation's support of science serves as the backbone of basic research in this country. I support the President's efforts to double the NSF budget by fiscal year 1994, and this authorization keeps us on that time table.

An indirect cost amendment will be offered in a few minutes, as Mr. Boucher had described. I recommend that my colleagues support that amendment. I also want to urge you, Mr. Chairman, to work with the House leadership to bring this bill to the floor as soon as possible so that this committee can be the first to address this important issue legislatively.

[The prepared statement of Mr. Walker follows:]

OPENING STATEMENT OF THE HONORABLE ROBERT S. WALKER
MARKUP OF H.R. 2282 - NSF AUTHORIZATION

Mr. Chairman, I want to add my support to this legislation. Mr. Packard and Mr. Boucher have worked hard to bring a responsible bill before the Committee, and I commend their efforts. H.R. 2282 funds NSF at the President's request, and at the same time, reflects the Committee's concerns and priorities. I want to thank Mr. Packard for his amendment at Subcommittee to ensure fiscal responsibility in the out years.

The National Science Foundation's support of science serves as the backbone of basic research in this country. I support the President's efforts to double the NSF budget by FY 1994, and this authorization keeps us on that timetable.

An indirect cost amendment will be offered in a few minutes. I recommend my colleagues to support that amendment. I also want to urge you, Mr. Chairman, to work with the House leadership to bring this bill to the floor as soon as possible so that this Committee can be the first to address this important issue legislatively.

Mr. **Brown**. Thank you very much, Mr. Walker, and let me assure you that the Chair will follow your advice on that matter.

Does any other member desire to be heard before we recognize Mr. Packard for a motion?

[No response.]

If not, Mr. Packard, you're recognized for an appropriate motion.

Mr. **Packard**. Mr. Chairman, I move that the subcommittee now adopt the report.

Mr. **Brown**. We've heard the motion. Is there a second?

Mr. **Boucher**. Second.

Mr. **Brown**. I hear a second.

All those in favor, signify by saying aye.

[Chorus of ayes.]

Opposed, no.

[No response.]

The ayes have it.

The subcommittee report is adopted, and the bill is open for discussion.

Does any member wish to be heard on the bill before we accept amendments?

[No response.]

If not, the Chair will be glad to recognize Mr. Boucher for his amendment.

Mr. **Boucher**. Mr. Chairman, I have an amendment at the desk, and I ask unanimous consent that it be considered as read.

Mr. **Brown**. Without objection, so ordered.

Mr. **Boucher**. Mr. Chairman, the Subcommittee on Science held two days of hearings on the general subject of indirect cost recovery, and in cooperation with the Republican leadership of the subcommittee and the full committee, we have now structured an amendment that is the product of those hearings, and I'm very pleased to be joined in the co- sponsorship of that amendment by Mr. Walker, Mr. Packard, and Mr. Fawell.

The amendment sets a 26 percent cap on the administrative portion of indirect costs. That is a weighted average of administrative costs for universities that receive the largest amounts of Federally funded research. Indirect costs for items such as libraries, operation and maintenance, groundskeeping, light and heat in buildings, and equipment depreciation will continue to be reimbursed on the basis of the actual costs that are incurred. The amendment requires that funds that are provided to universities as depreciation reimbursement for buildings and equipment must be dedicated to the repair of research facilities, to their construction, to their renovation, or to the purchase of scientific equipment, ensuring that monies that are provided for those purposes are in fact spent for facilities and for equipment for research.

The real problem that has been identified by the Energy and Commerce Committee in its investigation and by the Science Subcommittee of this committee during the course of its hearings has been the inexactitude of determining which costs are in fact allowable and which are not as indirect costs of Federally funded research, and in order to address that problem, our amendment creates a panel that will be chaired by the Director of the Office of Science and Technology Policy that will be charged with determining what costs should be allowed and giving very clear guidance to universities with regard to that matter. The panel also is directed to examine and improve the methods of substantiating the claims for reimbursement that universities are making.

Mr. Chairman, that is a brief description of the amendment which is before the subcommittee. I'm pleased to commend it for the committee's consideration and would be pleased to yield to the gentleman from California, Mr. Packard, for his comments.

[The amendment proposed by Mr. Boucher follows:]

TB916

AMENDMENT TO H.R. 2282

OFFERED BY MR. BOUCHER, MR. PACKARD, MR. WALKER, AND MR. FAWELL

Page 4, after line 16, insert the following new section:

SEC. 3. ADMINISTRATIVE INDIRECT COST REIMBURSEMENT.

(a) DEFINITIONS.--For purposes of this section--

(1) the term ``administrative indirect costs'' means general administrative and executive expenses, departmental administrative and support services, and sponsored projects administrative expenses, and does not include expenses incurred for the operation, maintenance, preservation, and protection of the institution's plant, expenses incurred for the operation of the library, expenses incurred for the administration of student affairs and services to students, or depreciation or use allowances for buildings and equipment;

(2) the term ``direct costs'' means costs that can be identified specifically with a particular federally sponsored project;

(3) the term ``facilities primarily devoted to research'' has the meaning given such term pursuant to section 204(c)(1) of the National Science Foundation Authorization Act of 1988;

(4) the term ``indirect costs'' means costs incurred

for common or joint objectives that include, but cannot be identified specifically with, a particular federally sponsored project;

(5) the term ``institution of higher education'' has the meaning given such term in section 1201(a) of the Higher Education Act of 1965;

(6) the term ``modified direct costs'' means those direct costs which consist of salaries and wages, fringe benefits, materials and supplies, services, travel, and subgrants and subcontracts up to $25,000 each;

(7) the term ``renovation'' has the meaning given such term pursuant to section 204(c)(1) of the National Science Foundation Authorization Act of 1988; and

(8) the term ``repair'' has the meaning given such term pursuant to section 204(c)(1) of the National Science Foundation Authorization Act of 1988.

(b) ADMINISTRATIVE INDIRECT COST RATE.--Financial assistance provided by the National Science Foundation to an institution of higher education may include an amount for administrative indirect costs of the institution, at a rate not to exceed 26 percent of the modified direct costs of the project.

(c) NON-ADMINISTRATIVE INDIRECT COSTS.--Financial assistance provided by the National Science Foundation to an institution of higher education may include an amount for non-administrative indirect costs of the institution.

(d) BUILDINGS AND EQUIPMENT.--Amounts paid, in connection with financial assistance provided by the National Science Foundation to an institution of higher education, for depreciation or use allowance may only be used for construction, renovation, or repair of facilities primarily devoted to research owned by the institution of higher education, or for the purchase of equipment necessary to conduct scientific or engineering research.

(e) CERTIFICATION.--The chief financial officer of an institution of higher education receiving financial assistance from the National Science Foundation shall certify to the Director of the National Science Foundation at the end of each fiscal year that all expenditures reported in connection with a claim for indirect costs during such fiscal year were made for appropriate purposes, and that all amounts received for depreciation or use allowance with respect to buildings or equipment have been expended or are reserved for appropriate purposes in accordance with subsection (d).

(f) FAILURE TO COMPLY.--If the Director of the National Science Foundation determines that an institution of higher education has expended financial assistance in violation of this section, the Director shall recover from the institution of higher education an amount equal to the amount improperly expended, together with interest on such amount at a rate to be determined by the Director. Such amounts may be recovered through an offset against indirect cost awards to the institution of higher education in the subsequent fiscal year, or through a civil suit.

(g) COMMITTEE DETERMINATION.--

(1) ESTABLISHMENT AND PURPOSE.--The Director of the Office of Science and Technology Policy shall establish a committee whose purpose shall be to--

(A) identify which costs associated with federally funded projects can be properly allocated as--

(i) direct costs; and

(ii) the various categories of indirect costs, including buildings and equipment depreciation and use allowance; and

(B) examine the current practices of institutions of higher education in allocating costs for library expenses and for operation and maintenance of research facilities, make recommendations based on its finding as to the appropriateness of such practices, and determine whether changes in such practices are necessary.

(2) MEMBERSHIP.--The committee established under this subsection shall include--

(A) a representative of the Department of Health and Human Services;

(B) a representative of the Department of Defense;

(C) a representative of the Department of Energy;

(D) a representative of the National Science Foundation;

(E) a representative of the Office of Management and Budget;

(F) not more than 5 representatives of the higher education community, to be selected by the Director of the Office of Science and Technology Policy, of whom at least one shall represent researchers and at least one shall represent an institution of higher education which is not ranked among the top 100 of the institutions receiving Federal research and development funding; and

(G) the Director of the Office of Science and Technology Policy, who shall serve as Chairman of the committee.

(3) REPORT.--The committee established under this subsection shall submit to Congress a report containing its final identification under paragraph (1)(A) and the results of its activities under paragraph (1)(B), within 5 months after the date of enactment of this Act.

(h) EFFECTIVE DATE.--Subsections (b), (c), (d), (e), and

(f) of this section shall take effect with respect to financial assistance provided after September 30, 1991.

Redesignate the subsequent section accordingly.

Mr. **Packard**. Thank you, Mr. Chairman.

I again want to thank the subcommittee chairman for his work and his cooperation in crafting this piece of legislation. I think the members of the committee are fully aware that there are universities that have been struggling on the question of indirect costs in this country, and yet they do a significant amount of the research, and we want to not only promote and encourage these universities in their research programs, but certainly we want to remove a lot of the ambiguities and a lot of the confusion that has existed in terms of what in reality should be included in indirect costs.

Thus, this bill is designed to be an umbrella that cuts across Federal agencies which will support research at universities, but at the same time clarify the procedures that they must operate under. Despite the fact that we will be working toward this goal, it is still important that we mandate standards today in the NSF authorization bill.

As the umbrella interagency bill moves from committee to committee, we have no clear-cut time frame as to when it will actually be enacted. Therefore, it is essential that the Science Committee take the lead in this area and move the bill to the floor as quickly as possible.

The amendment being offered today is truly a collaborative effort that has been worked out by the subcommittee. I think we have all realized that a fixed rate is not a viable option at the present time. The cap, on the other hand, has achieved a certain level of consensus, mainly because it requires that universities still have to account for their indirect costs.

Again, I appreciate the work of the members of the subcommittee and the Chairman, and I commend the amendment to the full committee as perhaps the best approach to address the indirect costs in clarifying the ambiguities that the universities have been working under for some time.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Packard follows:]

STATEMENT OF
THE HONORABLE RON PACKARD (R-CA)
FULL COMMITTEE MARKUP
AMENDMENT ON INDIRECT COSTS TO NSF AUTHORIZATION ACT
5-22-91

I WOULD LIKE TO THANK THE CHAIRMAN OF THE SCIENCE SUBCOMMITTEE, MR. BOUCHER, FOR HIS WORK ON THE SUBJECT OF INDIRECT COSTS OF UNIVERSITY RESEARCH. I WOULD ALSO LIKE TO ECHO THE SENTIMENTS OF CHAIRMAN BOUCHER THAT THIS MARKS THE INITITAL STAGES OF A PROCESS THAT WE HOPE WILL EVENTUALLY TURN INTO AN UMBRELLA BILL THAT CUTS ACROSS FEDERAL AGENCIES WHICH SUPPORT RESEARCH AT UNIVERSITIES.

DESPITE THE FACT THAT WE WILL BE WORKING TOWARDS THIS GOAL IT IS STILL IMPORTANT THAT WE MANDATE THESE STANDARDS TODAY IN THE NSF AUTHORIZATION BILL. AS THE UMBRELLA, INTERAGENCY BILL MOVES FROM COMMITTEE TO COMMITTEE WE HAVE NO CLEAR-CUT TIME-FRAME AS TO WHEN IT WILL ACTUALLY BE ENACTED. THEREFORE, IT IS ESSENTIAL THAT THE SCIENCE COMMITTEE TAKE A LEAD IN THIS AREA AND MOVE THE BILL TO THE FLOOR AS QUICKLY AS POSSIBLE.

THE AMENDMENT BEING OFFERED TODAY IS TRULY A COLLABORATIVE EFFORT THAT WAS WORKED OUT AT THE SUBCOMMITTEE LEVEL. I THINK WE HAVE ALL REALIZED THAT A FIXED RATE IS NOT A VIABLE OPTION AT THE PRESENT TIME. THE CAP, ON THE OTHER HAND, HAS ACHIEVED A CERTAIN LEVEL OF CONSENSUS, MAINLY BECAUSE IT REQUIRES THAT THE UNIVERSITIES STILL HAVE TO ACCOUNT FOR THEIR INDIRECT COSTS.

I WOULD AGAIN LIKE TO THANK CHAIRMAN BOUCHER FOR WORKING WITH ME ON THIS ISSUE IN SUCH A COOPERATIVE SPIRIT. I WOULD ALSO LIKE TO THANK THE RANKING REPUBLICAN OF THIS COMMITTEE, MR. WALKER, AND A MEMBER OF THE SUBCOMMITTEE ON SCIENCE, MR. FAWELL, FOR THEIR INTEREST, INPUT, AND SUPPORT OF THIS ISSUE.

Mr. **Brown**. Do you have anything further to add, Mr. Boucher?

Mr. **Boucher**. Well, Mr. Chairman, I would yield to the gentleman from Pennsylvania.

Mr. **Walker**. Thank you, Mr. Chairman.

I appreciate your yielding, Mr. Boucher.

Mr. Chairman, with this amendment, we'll hope that the yacht stops sailing at the taxpayers' expense. The amendment addresses the issue of administrative costs head-on by imposing a 26 percent cap. The committee established to look at allowable and unallowable indirect costs is also charged to examine the operation and maintenance expense and library expense to determine if problems in those areas exist. By adopting this amendment today, the Science Committee will demonstrate its recognition of the current problems and its commitment to developing a solution which will protect the taxpayers and at the same time preserve our Nation's strong university research base.

I understand the National Science Foundation is aware of our efforts here today and does not oppose this amendment.

The **Chairman**. Does any other member desire to be heard?

Mr. **McMillen**. I would like to pose a question to the gentleman from Virginia with regard to this amendment.

In the definition of indirect costs, you exclude, obviously, maintenance and those kinds of costs, and you exclude depreciation as well. In these kinds of indirect allocations, is there anything else that's ever included with regard to infrastructure? Would there be interest costs sometimes included? Amortization of principal or interest?

Mr. **Boucher**. The answer is yes. We have defined, as I think you will see beginning on line 3, administrative indirect costs to be "general administrative and executive expenses, departmental administrative and support services, and sponsored projects administration expenses." That's the principal definition. What we're mainly talking about there is salaries and expenses of administration itself.

The items that the gentleman refers to would fall within the category defined beginning on line 6, which is everything else that typically today is thought of as indirect costs, and that would involve infrastructure, maintenance, repair, and the amortization of long term costs associated with that.

Mr. **McMillen**. Well, the only reason I asked the question is because it wasn't clear to me, but I wanted to make sure that the record at least showed this. I'm not that familiar with the issue, but the amortization of interest and principal could very well be included in some of these research allocations, but that is not intended to be part of your cap. Is that correct?

Mr. **Boucher**. The gentleman is correct. That would not be subject to the 26 percent cap.

Mr. **McMillen**. I thank the gentleman.

The **Chairman**. The gentleman from Illinois?

Mr. **Fawell**. Thank you, Mr. Chairman.

I certainly do support this amendment. I think all of us realize that there have been some fairly egregious requests here for reimbursement for yachts and grand pianos and parties for the dean and things of this sort, so I commend Mr. Boucher and Mr. Packard for certainly addressing this subject, and the one area of the amendment that I think is extremely important is that portion which pertains to depreciation.

It has always—I should say since being aware of these problems, it has seemed to me that the Federal Government even giving Federal funds in grants for depreciation is somewhat questionable. In all of the hearings in regard to which I had the opportunity to put some questions in, I found that when universities or grantees received these funds for, let us say, $20,000 to cover depreciation on a particular capital asset, they simply used that $20,000 for whatever purposes they wanted to use it. They didn't put it into a reserve account, for instance, and that violates certain basic common sense principles that if you're not going to actually use the taxpayers' money for the purposes for which the money is being given to you, you should return it.

This amendment goes definitely in the right direction by saying that if you're going to be receiving, let us say, $20,000—and I'll just use an example—for depreciation on something like, say, a nuclear reactor, you'll put it into a reserve account and, hopefully, the reserve account that pertains to that reactor so that in later years, when you have an outmoded reactor, you won't have to lean as heavily upon the Federal Government perhaps for aid in being able to do something about strengthening the country's science infrastructure.

My only constructive comment in reference to the amendment as it pertains to depreciation, Mr. Chairman, would be that I note the language in the amendment states that there will be a reserve account, and the portion of the grant that pertains to depreciation has to be placed in the reserve account, and that reserve account then wouldn't be a true reserve account, but it would be in a special account, and it would be used to reconstruct or capital improvements—even repairs, which are not capital improvements—of facilities primarily devoted to research in general and for, in general, the purchasing of equipment necessary to conduct scientific and engineering research.

My only constructive comment—and I certainly do support the amendment—but I would think we might want to give thought and consideration to having the money which is given for depreciation actually going to a reserve account for the particular buildings and/or capital assets for which the depreciation is claimed. That is to say, if it's being claimed, let's say, for a reactor or synchrotron or a given building, that would be put in the reserve account that pertains to those particular capital assets, being capital assets and being research in regard to which, obviously, this committee is interested or we wouldn't be giving money in the first place, rather than being able to be used for rather broad and general purposes all pertaining to research, but it could be for a research program involving the sex life of a monkey, for instance, rather than to pertain to the particular capital assets or the building, as I have said, in regard to which the Federal funds are being given in the first place.

Nevertheless, we've come a long way, and we have, I think, a very constructive and helpful amendment here. I would only hope that perhaps we could give more thought to narrowing the reserve accounts so we know that that money then is going to be held for the specific reinforcement in the future years of those particular capital assets and/or buildings in regard to which the Federal funds are being granted in the first place. So I do wholeheartedly support the amendment.

Mr. BOUCHER. Would the gentleman yield?

Mr. FAWELL. Yes, I would be very glad to yield.

Mr. BOUCHER. I want to thank the gentleman from Illinois for his contribution to the construction of this amendment and for recommending during the course of our hearings that there be a dedication of the monies received by the university for depreciation of buildings and equipment for further research purposes. The gentleman has made an enormous contribution in that regard.

I think his idea this morning is interesting, and I would say to the gentleman that I will be happy to engage in discussions with him between the time this bill is reported from committee and considered on the floor, and I hope that would be satisfactory.

Mr. FAWELL. It certainly is, and I thank the gentleman.

Mr. HENRY. Mr. Chairman, I have an amendment to the amendment and would ask the clerk to distribute it to the members of the committee.

Let me summarize the amendment very quickly and then speak to it. It would strike the effective date of September 30, 1991, and instead insert June 30, 1992, so it's a very simple amendment.

If I may just make a few comments, Mr. Chairman. First of all, I want to acknowledge Mr. Boucher's fine work on this and his cooperation with both sides of the aisle, and I have absolutely no disagreement whatever with what he's trying to do, nor even with the substance of the language which is before us. What has come to light in recent months with Mr. Dingell and others is obviously outrageous. The American public is rightfully outraged, and we ought to address these abuses as well.

It's interesting—I ran into a book by Howard Cosell which is on college and university sports and what's wrong with sports. There's a great interchange between Bart Giamatti, the former president of Yale University and former baseball commissioner, of analogy between college sports and research grants as making money, and I think Mr. Boucher might get a kick out of this interview.

"Dr. Giamatti, in your view, are big time college sports bad for our schools?" "Yes, very bad insofar as they commercialize undergraduates for the purpose of producing revenue." "What about the argument that big time college sports revenues support the minor sports programs"—I'm cutting through this—"thus making fencing or field hockey available to students who desire such sports?" I'll get to the subject of this in just a second. You'll love the quote.

[Laughter.]

Mr. HENRY. "I'm not sure that they really see the case to begin with, Howard, but the idea that a school would justify abuses and corruption of football or basketball in order to provide fencing is an appalling argument, both morally and legally. There can be no distinction between major sports such as football and minor sports such as lacrosse. These distinctions instigate part of the trouble. It's like saying that Yale has a physics department, so it's revenue can support the philosophy department." "Is there an analogy here?" "Absolutely. There's a very strong analogy between academic departments that bring in revenue in intercollegiate sports. Howard, people just don't understand that the real big time and real big money that comes into research universities is not from sports, but from the Federal research money. That is the money that supports the schools, not sports revenue." "Would you elaborate?" "Certainly."

Now, I like to think Dr. Giamatti was speaking a bit metaphorically as he cites figures. Fortunately for him, we can't bring him to committee. "Let's say a school gets $1 million from the Defense Department for research. That $1 million goes to support the real cost of doing the research— the light for the rooms, the heat, the air conditioning, the basics. Then you get what's called indirect recovery money to support the research, and that's 65 percent to 72 percent above the $1 million. The kind of money I'm talking about swamps the big time college sports money, and all the big time schools get this research money ever since the Manhattan Project."

Now, whether his figures were metaphorical or not, I'm not in a position to judge, but obviously there's a problem here. Obviously, we are absolutely right in seeking to address it, and I use that outlandish quote for trying to disabuse any notion that the amendment I'm offering is trying to get the universities off the hook where abuses have occurred, and they have occurred.

My concern is simply this. The major universities, as well as the smaller colleges and small universities, your non- research institutions—your higher education academic institutions run on a July 1 to June 30 fiscal year, and what you've done is you are triggering into two fiscal years with this language contracts that are already out not just through NSF, but National Institutes of Health, and changing the rules midway through contract language that's already out there.

So what I'm really trying to do—it would still have impact on this budget year, because the June 30, 1992, cutoff will still get three months of savings, as it were, in the 1992 Federal fiscal year, but it doesn't get you in the situation of all kinds of potential litigation, which I do think is there, of changing terms of cost recovery, of allocation, on a very, very unsettled basis, first of all, for those that are already out from NSF that were put out this year, and secondly, you're definitely getting into two college fiscal years with two different systems of review, and I'm just trying to deal with that.

I am a little disappointed that Mr. McMillen had to leave for another committee meeting, because his question to Mr. Boucher was exactly on target—exactly what is indirect, what is direct, how do we amortize—and what we have done is we've picked the 26 percent figure, and that may or may not be the right figure, but also we admit, even in the amendment that's been introduced, the lack of certitude as to exactly what we're doing. I mean this not as a criticism, because we've got to start somewhere and we want to move on this, but you'll notice that on pages 4 and 5 of the amendment that we establish the committee in the Office of Science and Technology Policy to resolve further and allocate questions of direct cost and various categories of indirect cost and examine current practices. In other words, we're establishing a guideline of 26 percent, not quite knowing how we got there, although we're saying that seems to be the average, but not knowing what's there.

So my amendment is not meant, quite frankly or very honestly, to give cover to anyone, but to be honest in terms of that we're triggering into current contracts which have the potential for litigation and creating absolute chaos in that next academic year and grant process in terms of proposal review and cost allocation. So I offer the amendment as a good faith amendment.

I would also point out that when Energy and Commerce did its language on this, they put in a waiver for where you were going to have problems with amendments that would bankrupt a contractor or bankrupt a research project. Now, obviously, they acted before we did, and the attempt here is, of course, with Energy and Commerce with its National Institutes of Health and our committee with NSF and across the board, to get to some kind of bottom and comprehensive universal boilerplate policy. I just thought we have an inconsistency as it is. That's not to say it's not justifiable or ours isn't better language, but it's going to need refinement, and I suspect that one of the areas in which it's going to need refinement is on the issue of the date of effect.

I'm wondering maybe, Mr. Boucher, since I think you realize my intentions are well-motivated, perhaps you could respond to some of the issues I've raised with this.

[The amendment proposed by Mr. Henry follows:]

page 6, line 2, strike "September 30, 1991" and insert "June 30, 1992".

Mr. BOUCHER. Will the gentleman yield?

Mr. HENRY. I'd be pleased to yield.

Mr. BOUCHER. I thank the gentleman for his comments, and particularly his quote from the person who I admire greatly, Mr. Giamatti. It is with great reluctance, therefore, that I rise to oppose the gentleman's amendment, and I would offer several comments in that regard.

The amendment would actually have this new set of procedures and the 26 percent cap on administrative indirect costs go into effect on June 30, 1992. That would be in the middle of a fiscal year. The indirect cost rates for universities are negotiated on a fiscal year basis. So I would suggest to the gentleman that rather than resolve confusion by having his amendment become effective in the middle of a fiscal year, it might well serve to promote even further confusion.

The gentleman has suggested that we have established in the bill a panel to be chaired by the Director of OSTP for the purpose of determining what indirect costs are allowable and which are not and what indirect cost pools the various costs should be assigned to, and he is correct in that statement. The reason this is being done is not because we want fundamental changes in the way that universities currently interpret the practice. We want some uniformity generally.

The problem that exists today is that the OMB Circular a)21 is so imprecise in the way that it defines what allowable indirect costs are that we have seen the kind of abuse that was uncovered in the Energy and Commerce Committee's hearings and in our subcommittee's hearings as well. A lot of that simply arises from imprecision in definition. A lot of it arises from misinterpretation by the universities as to what should be allowed and what should not be allowed.

So rather than promote confusion, I would suggest to the gentleman that our purpose in establishing this new panel is to resolve the confusion that currently exists.

Mr. HENRY. Would the gentleman—

Mr. BOUCHER. Let me simply finish this thought, and then I'll be pleased to yield.

To the extent that there is guidance today to the universities through A-21, that would continue. We're not interrupting that process. We're not terminating the application of Circular A-21. So the universities, to the extent that they're currently relying on it, can continue to do so. But as soon as OSTP's new panel comes forward with recommendations for better rationalizing that system, then I would suggest that the universities would have better guidance.

So I simply take issue with the suggestion that somehow the intrusion of this new panel into the process would cause more confusion. My firm belief is that it would lessen it.

Mr. HENRY. If I could just reclaim my time under the Chairman's generous gavel here to respond to you, the issue here, though, of course, is the universities' fiscal year in accounting versus the Federal fiscal year. I mean, you can go either way, but you're immediately getting yourself in a situation where the rules of the game change halfway through on a contract that's already entered into.

I think what I'm really—I'm not questioning what the gentleman is saying other than to say he is indicating that the very types of clarification that I'm suggesting are unresolved are in fact unresolved, and if we put an effective date which is premature, it, I think, is going to create problems not only for the universities, but the NSF, et al., and I do remind the gentleman that our language is not consistent with that over in Energy and Commerce.

I'm simply saying we're going to have to fine-tune this. That's really what I'm saying.

Mr. BROWN. The time of the gentleman has expired.

The Chair will recognize Mr. Wolpe, who has been seeking recognition, and then we'll recognize the gentleman from Kansas, Mr. Glickman.

Mr. WOLPE. Thank you very much, Mr. Chairman.

I want to associate myself with the expression of concerns that Mr. Henry has raised, and I'd like to perhaps pursue a couple further questions, if I may, of Chairman Boucher.

Let me say first of all, like Mr. Henry, I agree fully with the importance of establishing a policy. It seems to me there are two separate issues that have arisen in the course of these revelations recently. One is that there has been significant abuse, and those abuses have got to be ended. The second is that there is clearly no uniform standard in place as it relates to Federal research being conducted at colleges and universities across this country. Different departments have different programs and different approaches to this very question. So there should be some uniformity, and it's important that the work of this committee be done, I think, cooperatively with other committees that have some jurisdiction in this area so we can end up with a uniform standard. I agree with all of that.

The concern that I have is the impact of the timing of this new policy on universities that may or may not have engaged in any pattern of abuse. My understanding is that there are still many audits that are being undertaken, the results of which will not even be known until the summer, and we don't have a clear fix, therefore, on the pattern of abuse, and I guess the question I'd like to ask Mr. Boucher—under this language, is it not conceivable that institutions that have engaged in no abuse whatsoever but had an authorized understanding from the Federal Government with respect to its accounting of indirect costs might be severely financially penalized without the opportunity to phase into the new policy? I mean, that's my concern. It's a question of timing and the kind of notice that these institutions would have.

Mr. BOUCHER. Will the gentleman yield?

Mr. WOLPE. I'd be pleased to yield.

Mr. BOUCHER. The answer to the question is that universities would have until the upcoming fiscal year in order to become acquainted with the new set of rules, and that should be a sufficient amount of time with respect to contracts that would be negotiated thereafter and indirect cost rates that would be negotiated thereafter.

The gentleman is suggesting that some universities might be penalized. I think it is possible that after the 26 percent cap on administrative costs goes into effect that some universities might receive less in indirect cost reimbursements overall than they're receiving today, but we have calibrated these numbers in such a way that the total amount of money spent on indirect costs will be roughly equivalent to what is spent at the present time.

The current national average for indirect cost recovery is 51 percent of modified direct costs. When you add the 26 percent cap for administrative indirect costs to the amounts that would be provided in the other category, which is all other indirect costs—operations and maintenance, groundskeeper salaries, building depreciation, and equipment depreciation—you come virtually to the 51 percent that is the national average today. So overall, universities would not be penalized. What we would have is a rationalization of a system that today needs much further definition and refinement. That is our effort, to provide it.

Mr. WOLPE. Well, if I may reclaim my time, again, I have no quarrel with the importance of rationalizing the system and ending up with a standard that will in fact be implemented. I think that's long overdue. My concern is, if I understand what you're saying, that there could in fact be institutions who, through no fault of their own, would find themselves severely penalized financially without a heck of a lot of time and notice to adjust in terms of their own institutional operations.

So the question that I would pose—I mean, how weighted are we to this particular time frame? Is there some way we can find to—I'd like to have some clear understanding as to what the impact will be on specific institutions. Just because it's the national average, it's not going to be much consolation to institutions that are caught up in this new formula, again, even without necessarily having engaged in any pattern of abuse whatsoever.

Mr. BOUCHER. Would the gentleman yield one more time? I'll be very brief in this response.

If the amendment offered by the gentleman from Michigan is adopted, the new rules would not become fully effective until fiscal year 1994. They would become effective during the middle of fiscal year 1993. That's a terribly long time, I would suggest, to delay the implementation of a plan to rationalize this system.

The amendment that we are proposing, the amendment in chief, would make the new system effective at the beginning of the upcoming fiscal year, and that, it seems to me, is a sufficient amount of time for universities to acquaint themselves with what is really just a cap on administrative indirect costs. The balance of the provisions would establish a panel that would conduct its work over a fairly long period of time and ultimately provide greater guidance to universities.

I would say this to my friend from Michigan, that we are in a collaborative process at the moment with the Health and Environment Subcommittee of the House Energy and Commerce Committee that has inserted a similar—not identical, but similar—proposal, the NIH authorization. We are continuing our discussions. We hope ultimately—and when I say ultimately, I mean by the end of this year—to have umbrella legislation that can be passed and applied to all Federal agencies that fund university research. That obviously would be referred to a number of other committees that have authorizing jurisdiction. We're in discussions with them as well. When that umbrella legislation is adopted, it would supersede this provision, the provision of the NIH authorization, and, in fact, any indirect cost recovery provision contained in any measure that is law at that time.

Now, there is ample opportunity there for us to work cooperatively with the gentleman from Michigan, and I will certainly give my pledge to do that, to ensure that no university is caught off guard, that no university is hampered in terms of a lack of knowledge as to how it will comply with these new rules, and I hope that the gentleman would find that pledge satisfactory.

Mr. BROWN. The time of the gentleman from Michigan has expired, and you're going to have your hands full with the gentleman from Michigan.

I recognize the gentleman from California, Mr. Packard.

Mr. PACKARD. Thank you.

I would simply like to respond that this is an extremely high-profile issue for universities. Almost all universities that are involved in research have been watching the process as this legislation has been moving. They're not going to be inclined to make contracts that would violate what they see coming down the pipe if they're in contract negotiations in this time.

In some instances, and I think it would be very minimal, there may be some need to go back and renegotiate contracts, but I don't sense that it would be significant, and, frankly, I think that there is such a need to clarify the issue and the universities want to know what the parameters are that they would like us to implement this as quickly as possible. I think it would be a mistake to delay it a full year simply because I think it would—they want the clarification now.

Mr. **Walker**. Would the gentleman yield?

Mr. **Packard**. I'll be happy to yield to Mr. Walker first and then to the gentleman from Missouri.

Mr. **Walker**. I thank the gentleman for yielding, because I think the gentleman makes a good point, and there's one other thing that we need to clarify here, and that is the gentleman from Michigan, Mr. Wolpe, referred to the fact that universities could be accused of abuse on all of this that were not abusing anything. This is not just about abuse. Obviously, that is one of the concerns based upon the hearings that have been held on Capitol Hill, but this is also about allocation of Federal monies.

We actually want to begin immediately the process of assuring that money is going to research and not to administrative costs, and so one of the reasons why we are putting this cap in place is to assure that the money actually gets to research. That's something we want to begin to have happen now. With the contracts that go out next year, we want universities to put the money into researchers rather than into administrative costs.

So this is not just a matter of trying to cure the abuse. While that is certainly something that we hope will result from this, we also want to make certain that the limited Federal dollars that are available are actually going to research activities.

I thank the gentleman for yielding.

Mr. **Volkmer**. I'd just like to echo the words of the gentleman from Pennsylvania. In fact, as I review what the primary amendment provides for—the one before us, not the amendment to the amendment—I think it's very generous when I consider that the taxpayers' money out here, the people that are working, are trying to say, "We need money for basic research" and then finding that millions of dollars are not going to basic research and we're still going to permit large amounts of money not to go for research, but to go for overhead, which I think personally that the universities or the State or somebody, the private institutions, the private contributors, they can afford those things.

I think it's more than generous, and I think that the amendment of the gentleman from Michigan is way out of line. I think it's time we put a stop to it, I think it's time to get going with the new rules, and if I had my way, I'd like to narrow it down even further.

Mr. **Packard**. Well, let me conclude my statement that most universities would not sue over this problem because it's such a high-profile issue, it has received so much adverse publicity on it, that the American people and the universities don't want to be engaged in improper methods. They look for guidelines, this gives them the guidelines, and I believe that they will make their contractual arrangements based on that.

Mr. **Brown**. The time of the gentleman has expired.

The gentleman from Kansas?

Mr. **Glickman**. Well, I suppose it's been said before, but I would say that I support this amendment. I think there may be some problems in the effective date, but I understand that you're going to work with Mr. Dingell's committee, and I would remind you that the largest, I think, single block of research dollars are in defense and agriculture, and there is other lack of standards in this whole area. But I do think that we owe a debt of gratitude to Mr. Dingell for what he did in terms of examining this problem. The fact of the matter is very few Americans knew that building depreciation, the keeping of grounds, the utilities were being paid for out of Federal research dollars.

Now, that may be historically necessary, there may be some reason for it, but it is very hard for taxpayers in this country to understand those kinds of things. What seems to happen on occasion is that a grant is given for a major new research project, and somebody has to build a building to house that grant, and somebody has to pay the utilities to house that grant, and somebody has to do the paper to house that grant, and, ultimately, Uncle Sam gets to pick up all the costs of that, and then it kind of becomes a vicious circle.

Now, maybe you've got to have that in order to have adequate research in this country, but I suspect that what we need is effective standards around America so people don't think that our research dollars are going to promote bureaucracy rather than actual research.

The other thing I would say is it's important that Congress asserts its role. I think you may have mentioned this before I came in here. We don't want the Office of Management and Budget to arbitrarily set standards which don't have validity in the law. It's our job to set those goals. And I think as long as we're up front with the universities and give them plenty of advance time to plan, they'll be able to cope very nicely.

Mr. Brown. The time of the gentleman has expired.

Who seeks recognition?

The lady from Missouri, Ms. Horn?

Ms. Horn. Mr. Chairman—

Mr. Boucher. Would the gentlewoman yield?

Ms. Horn. Sure.

Mr. Boucher. I understand the concern of some members that there may be an effect on long term contracts, multi-year contracts, when a new system for establishing a cap on indirect costs goes into effect. The answer simply is this. The indirect cost rates at universities are negotiated every year, and so there really would be no effect that is not present today, once this system goes into effect, on long term contracts.

If there is any lingering concern about that, I would be happy to engage in discussions with the gentlewoman or others who share that concern and plumb the issue somewhat more deeply. My belief as of the moment is that there would be no effect on long term contracts, given the fact that these indirect cost rates are negotiated every year.

Mr. Brown. The gentleman from Michigan?

Mr. Henry. Thank you, Mr. Chairman.

Given the nature of our discussion, I think the concern that I wanted to raise before the committee has reached a level of understanding, and I do want to reiterate to Mr. Boucher and others that I have not disagreed with anything that has been said on behalf of your language or what you're trying to do. That is not the issue. The issue is along the lines of the questions Ms. Horn raised along the lines as to whose fiscal year. I do want to clarify that the amendment as proposed was a nine-month delay to swing into the academic institutions' fiscal year, not a two-year delay.

But other than that, I know the gentleman is going to have to be working with the other committees and departments to get a base and uniform standard, and in light of our discussion, I would ask unanimous consent to withdraw my amendment.

Mr. **BROWN**. Without objection, the gentleman's request—

Mr. **RITTER**. Would the gentleman yield?

Mr. **HENRY**. I don't control the time.

Mr. **RITTER**. Who is controlling the time, just for a brief comment?

Mr. **BROWN**. Does the gentleman from Pennsylvania seek recognition? The gentleman is recognized for one minute.

Mr. **RITTER**. The indirect costs paid for by the Federal Government has created a kind of deep-pocket effect, whereby research supported by the Federal Government has often been more profitable than research supported by industry which couldn't quite come up with as much overhead as the Federal Government could and has helped to sway the priorities of university research toward the Federal Government's R&D economy and away from some of the more pertinent, some of the more pressing issues of global competitiveness, and I think it's something that I've seen over the years, and I think I just wanted to share that with members of the committee.

I yield back the balance of my one minute, Mr. Chairman.

Mr. **BROWN**. The Chair thanks the gentleman and recognizes his own keen interest and familiarity with this problem and the contribution that he has made.

The Chairman of the committee has assured me that he will work diligently to rationalize or to coordinate this amendment with the other appropriate committees and make sure that we have a uniform Government-wide policy dealing with this matter. Any change that we make that results only in the creation of a hodgepodge of different Federal regulations would be unacceptable to me, and I think it would be unacceptable to the subcommittee, and I feel assured that we are moving in the right direction here.

Any further debate on the amendment offered by Mr. Boucher?

[No response.]

Mr. **BROWN**. If not, the Chair will put the question.

All those in favor, signify by saying aye.

[Chorus of ayes.]

Opposed, no.

[No response.]

The ayes have it. The amendment is adopted.

Are there any additional amendments to be offered?

Mr. **TRAFICANT**. Mr. Chairman?

Mr. **BROWN**. The gentleman from Ohio?

Mr. **TRAFICANT**. I have an amendment, Mr. Chairman.

While members are getting the amendment, my amendment is supported by Howard Cosell. While speaking before a national midget football league awards banquet, he said that these universities aren't engaged in research, they're engaged in fraud, and since Congress won't really do anything about it, he supports the Traficant amendment. He said if they're going to buy yachts, the yachts should be made in America, and if they're supposed to be made in America, they better not lie about the labels, and if the President said that some country is practicing illegal trade, those companies can't even try and sneak in a yacht with an illegal label on it to be sold to the universities who have broken the law and should be disqualified.

Now, Congressmen Tanner and Costello were both there with me to hear this speech, and we agree with what he said, and there are three amendments offered en bloc. I ask unanimous consent that they be offered en bloc, and I ask that they be passed over without prejudice, supported wholeheartedly, and that we could move on.

[The amendments proposed en bloc by Mr. Traficant follow:]

TRAFIC063

AMENDMENT TO H.R. 2282
OFFERED BY MR. TRAFICANT

Page 4, after line 20, insert the following new section:

SEC. 4. BUY AMERICA PROVISIONS.

(a) RESTRICTIONS ON CONTRACT AWARDS.--No contract or subcontract made with funds authorized by an amendment made by this Act may be awarded for the procurement of an article, material, or supply produced or manufactured in a foreign country whose government unfairly maintains in government procurement a significant and persistent pattern or practice of discrimination against United States products or services which results in identifiable harm to United States businesses, as identified by the President pursuant to subsection (g)(1)(A) of section 305 of the Trade Agreements Act of 1979 (19 U.S.C. 2515(g)(1)(A)). Any such determination shall be made in accordance with such section 305.

(b) PROHIBITION AGAINST FRAUDULENT USE OF ``MADE IN AMERICA'' LABELS.--If it has been finally determined by a court or Federal agency that any person intentionally affixed a label bearing a ``Made in America'' inscription, or an inscription with the same meaning, to any product sold in or shipped to the United States that is not made in the United States, that person shall be ineligible to receive any contract or subcontract from the National Science Foundation, pursuant to the debarment, suspension, and ineligibility procedures in subpart 9.4 of chapter 1 of title 48, Code of Federal Regulations.

(c) BUY AMERICAN REQUIREMENT.--(1) The Director of the National Science Foundation is authorized to award to a domestic firm a contract for the purchase of goods that, under the use of competitive procedures, would be awarded to a foreign firm, if--

(A) the final product of the domestic firm will be completely assembled in the United States;

(B) when completely assembled, more than 50 percent of the final product of the domestic firm will be domestically produced; and

(C) the difference between the bids submitted by the foreign and domestic firms is not more than 6 percent.

(2) This subsection shall not apply to the extent to which--

(A) in the opinion of the Director of the National Science Foundation, after taking into consideration international obligations and trade relations, such applicability would not be in the public interest;

(B) in the opinion of the Director of the National Science Foundation, after consultation with the Secretary of Defense, compelling national security considerations require otherwise; or

(C) the President determines that such an award would be in violation of the General Agreement on Tariffs and Trade or an international agreement to which the United States is a party.

(3) This subsection shall apply only to contracts made for which--

(A) amounts are authorized by an amendment made by this Act to be made available; and

(B) solicitations for bids are issued after the date of enactment of this Act.

(4) The Director of the National Science Foundation, before January 1, 1993, shall report to the Congress on contracts covered under this subsection--

(A) entered into with foreign firms pursuant to a determination made under paragraph (2) of this subsection; and

(B) awarded to domestic firms pursuant to paragraph (1) of this subsection, in fiscal years 1991 and 1992.

(5) For the purposes of this subsection--

(A) the term ``domestic firm'' means a business entity that is incorporated in the United States and that conducts business operations in the United States; and

(B) the term ``foreign firm'' means a business entity not described in subparagraph (A).

Mr. **Brown**. Is this the one labeled "Traficant 063"?

Mr. **Traficant**. That is correct, Mr. Chairman.

Mr. **Brown**. And that contains the three different provisions?

Mr. **Traficant**. It does.

Mr. **Brown**. The Chair will consider the amendment as one single amendment. The Chair has reviewed the amendment and has no objections to it at this point. He might if the discussion continues too long, though.

[Laughter.]

Mr. Packard?

Mr. **Packard**. Mr. Chairman, this amendment we've seen, I think, essentially in its essential form before on many occasions, and this side has no objection.

Mr. **Traficant**. I yield back the balance of my time.

Mr. **Brown**. If there is no further debate, the Chair will put the question.

All those in favor of the Traficant amendment will signify by saying aye.

[Chorus of ayes.]

Opposed, no.

[No response.]

The ayes have it. The amendment is agreed to.

Are there further amendments?

[No response.]

If not, a motion is in order to consider any proposed committee views or report language. Do we have any proposed committee views or report language?

[No response.]

If not, the Chair will recognize Mr. Walker for a motion.

Mr. **Walker**. Mr. Chairman, I move the committee report the bill H.R. 2282, the National Science Foundation Authorization Act Amendments of 1991, and to instruct the staff to prepare the legislative report and to make technical and conforming amendments and that the Chairman take all necessary steps to bring the bill before the House for consideration.

Mr. **Brown**. You've heard the motion. Is there any further discussion on the motion?

[No response.]

If not, the Chair will put the question.

All those in favor, signify by saying aye.

[Chorus of ayes.]

Opposed, no.

[No response.]

The ayes have it, and the motion is agreed to.

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